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February 26, 2010

2010 Draft 303(d) List of Impaired Waters:
Consolidated Assessment and Listing Methodology
Janet Pittman
Rules Development Branch
Office of Legal Counsel, MC 65-46
Indiana Department of Environmental Management
100 North Senate Avenue
Indianapolis, Indiana 46204-2251

Re: Comments on 2010 Draft 303(d) List

Dear Ms. Pittman:

On behalf of Alcoa Inc., we are submitting these comments regarding the "2010 Draft List of Impaired Waters and Consolidated Assessment and Listing Methodology under Section 303(d) of the CWA." As described below, Alcoa believes that there are significant legal and scientific flaws in the draft list and methodology, which must be corrected before this document is finalized and submitted to U.S. EPA for approval.

I. LEGAL ISSUES

A. Aluminum Values

IDEM's development and use of the aluminum values for its draft 303(d) list violates several provisions of Indiana administrative law.

At a number of places in its 2009 Notice [hereinafter "Notice"], IDEM acknowledges that it is required by Section 303(d) of the CWA to determine those waters of the state that do not meet Indiana's "water quality standards." *See, e.g.,* Notice at 1 (IDEM is "required to assess its waters for compliance with the state's water quality standards (WQS)"); *Id.* at 19 (same). Indiana's "water quality standards" are standards formally promulgated by the Indiana Water Pollution Control Board ("Water Board") as "rules" after undergoing and complying with the full range of due process requirements required by Indiana law, including such safeguards as two 30-day public comment periods, a duty to evaluate and respond to comments, and a rulemaking hearing before the Water Board. *See, e.g.*, Ind. Code §§ 13-14-9-2; 13-14-8-3; and 4-22-2-24, -27, -28.

The aluminum values used in the draft 303(d) impairment determination are not "water quality standards" promulgated by the Water Board. Rather, these values have been developed by IDEM, not the Board, and are what IDEM generally refers to as "Tier I and Tier II criteria." The exact terminology for these values varies depending on whether the criteria at issue are for the Great Lakes Basin (where they are called Tier I Criteria and Tier II Values) or for "downstate" waters (where they are called Acute Aquatic Criteria (AAC) and the Chronic Aquatic Criteria (CAC)). In its Notice, IDEM notes that the process for deriving these two sets of criteria is the same for both up-state and downstate, and "to simplify" discussion, IDEM simply refers to these criteria in both geographic regions as "Tier I" and "Tier II" criteria. *See* 2009 Notice at 28. We will use the same simplified terminology here.

There is some uncertainty as to whether the aluminum criteria are, in fact, Tier I/II criteria because IDEM inconsistently refers to these numbers in its Notice at times as "Tier I and Tier II criteria" (*see, e.g.*, 2009 Notice at 29) and at other times as a "site-specific criterion calculated per Method 1 (327 IAC 2-1-8.3)." *Id.* at 30.[1] IDEM then goes on to

1 The section cited by IDEM (§ 8.3) does not in fact provide for calculating a "site-specific criterion"; it instead sets forth procedures for determining "chronic aquatic criteria." Perhaps IDEM meant to cite § 8.9 which *does* provide procedures for calculating "site-specific modifications to criteria." However, proceeding under § 8.9 requires a variety of due process steps that do not appear to have been undertaken with respect to aluminum.

state that "the resulting value is equivalent to a Tier I value and may be used as such for IDEM's 305(b) assessment processes." These differing classifications present several problems. For one thing, there is no provision in the Board rules to recognize the "equivalent" of a Tier I value. Second, if in fact the downstate aluminum value is a "site-specific criterion," then IDEM must proceed under the procedures for issuance of site-specific criteria, which clearly require a Board rulemaking. The bottom line here, from a legal matter, is that the Tier I/II criteria for aluminum were never promulgated by the Water Board, but rather were developed and adopted by IDEM without *any* apparent opportunity for public comment or input. These criteria were publicly announced by IDEM for the first time in the Notice as part of the basis for its impairment determinations without providing any prior opportunity for public review.

IDEM's Notice acknowledges the lack of due process in connection with developing these criteria. For example, IDEM's Notice states that "Tier I criteria meet all the requirements necessary to be incorporated into Indiana's WQS, *however they have not been promulgated into Indiana's Administrative Code*." *Id.* at 28 (emphasis added). Nevertheless, IDEM states "it is important to note that all [non-promulgated] Tier I criteria and Tier II criteria values *are valid for use in* ***all*** *IDEM regulatory processes* including 305(b) assessments and 303(d) listing decisions." *Id.* at 29 (bracketed word and emphasis added). This is erroneous. Perhaps in an effort to provide some "cover" for the lack of due process afforded in developing the Tier I/II criteria, IDEM also states that the "Tier I criteria and Tier II values criteria are treated as a numeric translation of the narrative criteria in

For the balance of this discussion, we will assume IDEM intended to develop Tier I/II criteria for these constituents although that is not entirely clear. Given the inconsistency in the Notice, and the fact that IDEM has not produced all background information or legal authority underlying these criteria, we reserve the right to supplement these comments once IDEM's actual basis for these numbers becomes clearer.

Indiana's WQS to determine whether the substance or substances in question are present in amounts sufficient to cause impairment to aquatic life." *Id.*2

The procedures in the Water Board's rules by which IDEM is purportedly authorized to calculate Tier I/II criteria without rulemaking by the Board are found at 327 IAC 2-1-6(a)(1)(E)(ii) and (iii), and 2-1-8.1 through 8.9. These rules are silent as to whether the Tier I and Tier II numbers must be promulgated. As relates to the Notice, neither the Water Board nor IDEM ever adopted the new Tier I/Tier II numbers (including aluminum) through rulemaking.3

IDEM candidly admits these non-promulgated Tier I/Tier II numbers are used for the *exact* same purposes as the promulgated criteria. Indeed, Tier I/Tier II numbers are used among other things to set NPDES permit limits, to determine what waters are impaired under the 303(d) program, and to allocate pollutant loading under IDEM's TMDL process – exactly like the Water Board's promulgated numeric water quality criteria. IDEM's use of these unpromulgated values as if they were validly adopted criteria is improper, and should not be sanctioned by the Board.

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2 "Narrative criteria" refer to provisions in the Water Board's water quality standards rule that set forth general narrative statements of desired water quality without any numeric criteria. A common narrative criterion is the so-called toxics criterion which provides that pollutants shall not be present "in amounts sufficient to be acutely toxic to, or to otherwise severely injure or kill, aquatic life, other animals, plants or humans. 327 IAC 2-1-6(a)(1)(E). Because these narrative criteria do not include corresponding numeric criteria in the WQS rule, they cannot be used to make impairment or TMDL decisions. Instead, the WQS rules set forth procedures to "translate" these general statements of intent into numeric criteria that can be compared to actual stream data. For reasons discussed below, the translation provisions of the Board's rules are also invalid.

3 IDEM could not adopt these as rules because IDEM lacks any statutory authority to promulgate such rules, and Indiana law makes clear that administrative agencies are creatures of statute and only possess those powers that the General Assembly gives them. *See Van Allen v. State*, 467 N.E.2d 1210 (Ind. Ct. App. 1984). Moreover, the Water Board has exclusive authority to adopt rules governing the water program. *See* Ind. Code § 13-18-3-1.

B. Tier I and Tier II Criteria

The Tier I/II criteria meet the definition of a "rule" under Indiana law and therefore must be promulgated. Indiana law defines a "rule" as "the whole or any part of an agency statement of general applicability that:

Section 1.01 has or is designed to have the effect of law; and

Section 1.02 implements, interprets, or prescribes:

(1) law or policy; or

(2) the organization, procedure, or practice requirements of an agency."

Ind. Code § 4-22-2-3(b). Tier I and Tier II numbers meet the definition of a rule because they are generally applicable, are designed to have the effect of law, prescribe policy, and implement and interpret law. *See, e.g., Indiana-Kentucky Elec. Corp. v. Commissioner*, 820 N.E.2d 771, 780 (Ind. Ct. App. 2005) (IDEM's requirement that ambient air quality monitors be within 10 km of the source was not related solely to IDEM's internal procedures, policies, or organization but instead met the three definitional requirements of a "rule").

<u>Generally Applicable</u>: The Tier I/Tier II numbers are generally applicable to waters of the State and to many dischargers. They are not merely used in one permit or to regulate one permittee. They are used to determine whether particular water bodies are impaired and therefore should be on the 303(d) list. They are used to develop and allocate pollutant loadings for multiple water bodies under the TMDL process. The numbers directly affect all existing and future dischargers to a water body on the 303(d) list. Indeed, IDEM has asserted in its Notice that these numbers "are valid for use in *all* IDEM regulatory

processes." Notice at 29 (emphasis added). IDEM is therefore treating these Tier I/II numbers as "generally applicable" within the meaning of this statute.

Effect of Law: The Tier I/Tier II numbers have the effect of law. They are a critical component of the 303(d) listing program that legally categorizes certain water bodies as impaired, which in turn has significant legal consequences. These numbers are used in the TMDL program and ultimately are used to tell people what they can and cannot legally discharge. If a water body is categorized as impaired using these unpromulgated values, the state becomes legally required to develop a TMDL, which will legally govern discharges to that water body. These numbers also will be used to establish legally enforceable NPDES permit limits outside the 303(d)/TMDL program. IDEM is using these unpromulgated values to create legally binding obligations on dischargers that could require the purchase and installation of expensive pollution control treatment facilities, and can lead to civil penalties or worse in case of violations. These numbers therefore create legal obligations and have the effect of law.

Implements/Interprets/Prescribes Law or Policy: The Tier I and Tier II numbers also "implement" law. IDEM is using these unpromulgated values to implement Indiana Code § 13-18-2-3, which requires IDEM to prepare a list of impaired waters by considering water quality data. The Tier I/II numbers are also used by IDEM to develop the list of impaired waters as required by both the CWA, 33 U.S.C. § 1313(d), and by Indiana Statute, Ind. Code § 13-18-2-3. Finally, the Tier I/II numbers "prescribe policy" because they announce to the state what is and is not an impaired water body. The rulemaking function "embraces [an] element of generality, operating upon a class of individuals . . . additionally, exercise of administrative rule making power looks to the future." *Blinzinger v. Americana Healthcare*

Corp., 466 N.E.2d 1371, 1375 (determining that the Indiana Department of Public Work's Medicaid rate freeze direction was "in the nature of a rule, and because it was not promulgated in compliance with statutory requirements [Ind. Code § 4-22-2-2], it is void and without effect."). The Tier I/II numbers have implications that are generally applicable and define legal obligations in the future. Those two components are fundamental characteristics of an agency action that requires a rulemaking procedure.

Because the Tier I and Tier II numbers meet the definition of a rule, they must be promulgated by the Water Board, to which the Indiana General Assembly has delegated exclusive rulemaking power over water quality related matters. This is not some meaningless technical requirement designed to "trip up" IDEM or the Board. There are important public policy reasons why these unpromulgated values should instead be developed and validly adopted only through the rulemaking process. In addition to giving effect to the General Assembly's directive, it allows the public, including the regulated community, to ask questions and to make suggestions as to how the regulations should be changed to be more technically accurate and reasonable; it provides a check on the decisions of unelected administrative officials before the actions of the public are restricted through actual laws; it requires an economic analysis as to the impact of the regulation to be conducted so the Board and public can make necessarily hard decisions about tradeoffs between economic impacts and water quality.4

4By proceeding as they have here, IDEM and the Board have been able to sidestep and ignore many mandatory due process requirements, including the following: Twenty-eight days prior to the adoption of a rule, IDEM must publish a notice of intent to adopt a rule including the intent and scope of the proposed rule in the Indiana Register. *See* Ind. Code § 4-22-2-23(b). The full text of the proposed rule must be published in the Indiana Register and notice of a public hearing must be provided. Ind. Code § 4-22-2-24. A statement regarding the availability of any supporting material for the proposed rule must also be included. *Id.* at (d). After publication of the proposed rule and notice of public hearing, IDEM must hold a hearing on the proposed rule. *Id.* at 4-22-2-26. All comments received at the public hearing must receive full consideration from IDEM. *Id.* at 4-22-2-

A TMDL based on these unpromulgated Tier I/Tier II numbers can force dramatic changes in discharge permits and therefore dramatic changes in the operations and activities of affected dischargers. They can have significant economic impacts by restricting or preventing expansion of existing operations or siting new operations that would discharge the constituents of concern. And from an environmental perspective, they provide the foundation of one of our most important water programs – to protect water quality and attain water quality standards. It is important that such efforts be subject to the processes established by Indiana law, and that the public be allowed to play its designated role in the process.

C. Narrative Criteria

In addition to the fact that Tier I/II criteria meet the definition of a rule that must be promulgated, IDEM's narrative water quality criteria rules are also invalid because they do not provide the requisite notice concerning what activity is prohibited. In its Notice, IDEM argues that the Tier I/II numbers are merely the "translation" of already promulgated narrative water quality criteria. It seems IDEM is trying to argue that since the public has already had the opportunity to participate in full due process procedures associated with the development of the narrative criteria, no more due process is required for this "translation."

Such an argument is without merit. The reason IDEM must "translate" the narrative criteria is because no one knows what they mean, and they cannot, standing alone, be

27. The Water Board may not adopt a rule until it has conducted at least two 30-day comment periods. *Id.* at 13-14-9-2. IDEM must provide the Water Board with a fiscal impact statement of the proposed rule prepared by the office of management and budget. *See Id.* at 13-14-9-4.2. The Indiana economic development corporation must review proposed rules to determine if alternatives exist to reduce the regulatory burden, and IDEM must respond to any comments the IEDC makes before the proposed rule can be adopted. *See Id.* at § 4-22-2-28. The final rule must be adopted within one year from the date that the notice of intent is published in the Indiana Register. Ind. Code § 4-22-2-25. After a rule is adopted, the agency must submit the rule to the attorney general and then the governor for approval. *Id.* at § 4-22-2-31, and -33. These are not trivial procedures to be lightly ignored. They are a cornerstone of our regulatory process to place limits on non-elected officials as they attempt to prescribe law and have constitutional underpinnings.

applied. They are unascertainably, perhaps unconstitutionally, vague. One cannot read the words of these narrative criteria and determine whether a water body meets those criteria. The narratives can only be used if they are translated into numeric criteria, which then can be compared to actual surface water quality data to make an impairment determination.

The narrative criteria are illegal. Indiana law requires that agency rules must be stated with "sufficient particularity" so that members of the public, including the regulated community, know what conduct is proscribed. The ascertainable standards doctrine prohibits agencies from promulgating regulations so vague or indefinite that a person of common intelligence must guess at their meaning and differ as to their application. *Ind. State Ethics Comm'n v. Nelson*, 656 N.E.2d 1172, 1176 (Ind. Ct. App. 1995); *Sterling Management-Orchard Ridge Apartments v. State Bd. of Tax Commrs*, 730 N.E.2d 828, 836-37 (Ind. Tax Ct. 2000). Even a genius – let alone a person of common intelligence – could only guess as to the meaning of the narrative criteria or what kinds of activity would be prohibited.

Moreover, the Board cannot seek to cure the illegality of the vague narrative criteria allowing *IDEM* to calculate nonvague standards to use in place of the vague narrative criteria—but without proper promulgation—at a later time. IDEM's calculation process essentially replaces the narrative criteria. It is interesting to note that IDEM consistently states that it cannot even modify an existing numeric water quality criterion without undergoing rulemaking. *See, e.g.,* Development of Amendments to 327 IAC 2-1-6 Concerning Sulfate Criterion in Waters of the State, LSA Document #07-185 ("The only option for revising a water quality standard contained in Title 327 is through rulemaking.").

Accordingly, the numeric numbers adopted to "translate" the narrative criteria must also be promulgated.

Even if the narrative criteria are not void for vagueness or being unascertainable standards, the Tier I/II criteria should still not be considered a mere translation of a promulgated rule for other reasons. To determine whether an agency action is merely an interpretation of a rule, federal courts have developed a body of law to determine what is a lawful vs. unlawful "interpretation." Under these cases, which are instructive here, to determine whether an agency is taking legislative action, a court determines whether the agency's action imposes new duties or creates new law. *See United States v. Zimmer Paper Products, Inc.*, 20 Envtl. L. Rep. 20,556, 20,557 (S.D. Ind. 1989). Courts utilize several criteria to determine whether the action imposes new duties or creates new law. First, courts consider whether the agency action "presently imposes a binding obligation or norm on a regulated firm or individual." *Id.* Second, courts ask whether the agency statement "genuinely leaves the agency and its decisionmakers free to exercise discretion" and noting that an interpretative rule "does not establish a binding norm." *Id.*

Third, courts also look to whether the agency action has imposed new and more stringent duties upon regulated entities. *Id.* at 20,558. Courts also look to whether the regulator views the regulations in their present form to be deficient when compared with the requirements of the interpretation. *Id.* at 20,559. Further, courts "give far greater weight to the language actually used by the agency in the past than to its present characterization of the rule." *Id.* at 20,447. Courts also consider whether the particular action is an action of the type that would benefit by the public comment process. *See Hoctor v. U.S. Dept. of Agriculture*, 82 F.3d 165 (7th Cir. 1996).

The rule versus interpretation factors strongly weigh in favor of the Tier I/II requirements being considered a rule that should be promulgated before it can be used by IDEM. The adoption of the Tier I/II numeric eliminates agency discretion regarding water quality. Under the narrative criteria, the agency has nearly unfettered discretion to determine whether a water body is meeting the narrative standards or not. But by "translating" the narrative criteria into an actual number, IDEM is left to do nothing but determine whether the waterbody's sampling data is higher or lower than the Tier I/II number and must classify the waterbody accordingly. The Tier I/II numbers are a necessary and essential part of the TMDL program which can greatly affect regulated entities as described above. While the unpromulgated Tier I/II values in and of themselves do not immediately affect the regulated community, their use in permits, the 303(d) listing process, and the TMDL program all impose new duties on those that are regulated.

In conclusion, the Water Board must promulgate the Tier I and Tier II criteria before IDEM can use them for permitting, 303(d) listing, or the TMDL program because:

(1) They fall under the definition of a rule and there are no regulations or statutes that suspend the rule promulgation requirement in this case.

(2) The narrative criteria that the Tier I/II are allegedly translating are unascertainable standards and void for vagueness.

(3) Even if the narrative criteria are not void for vagueness, the Tier I and Tier II cannot be considered a translation but instead are in effect an agency rulemaking.

D. Listing Methodology

In addition to the due process concerns for Tier I/II numbers discussed above, IDEM has committed other due process violations. Under Ind. Code § 13-18-2-3(b) the Water Pollution Control Board is required to promulgate a rule that establishes the 303(d) methodology used to identify waters as impaired and "specifies the methodology and criteria for including and removing waters from the list of impaired waters," IDEM has failed to initiate rulemaking on the mandatory requirement.

The General Assembly told IDEM and the Board that rulemaking safeguards must be provided for the 303(d) list methodology. IDEM is circumventing this statutorily dictated due process requirement by not moving forward with the methodology rulemaking. While the General Assembly may not have provided a definite deadline for promulgating the listing methodology rule, it certainly could not have intended that the task be delayed forever. IDEM has already proceeded through several listing cycles without following the statutory requirement. No further delay should be allowed; IDEM needs to move forward now, so that the rulemaking can be completed before the proposed 303(d) list is finalized and submitted to EPA.

II. SCIENTIFIC ISSUES

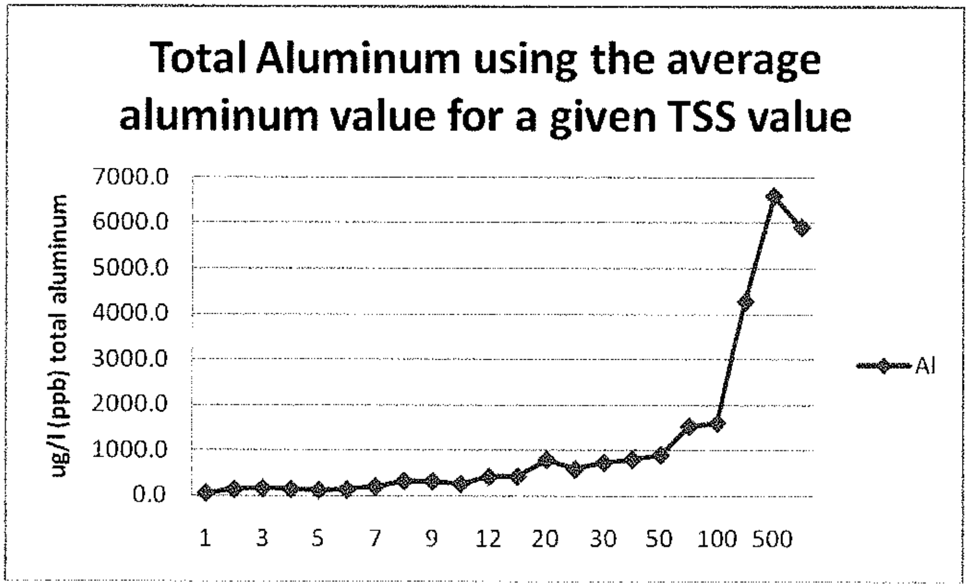
A. Flaws in Aluminum Database

The proposed aluminum values do not represent the best available science. A comprehensive study has been performed of the database used to develop EPA's aluminum criteria guidance and more recent studies. Based on that study (Attachment A), which was approved by the State of West Virginia (Attachment B), the State decided that for all waters other than trout waters, the appropriate chronic value for aluminum was 750 ug/l, applied on a dissolved basis. That water quality standard was first adopted on an interim basis, then for permanent purposes (Attachment C), and was approved both times by U.S. EPA (Attachments D and E). The same considerations would apply in Indiana. The proposed aluminum values used by IDEM in developing the draft 303(d) list are erroneous, and should be replaced after a careful consideration of the available data (in a rulemaking process, as discussed above).

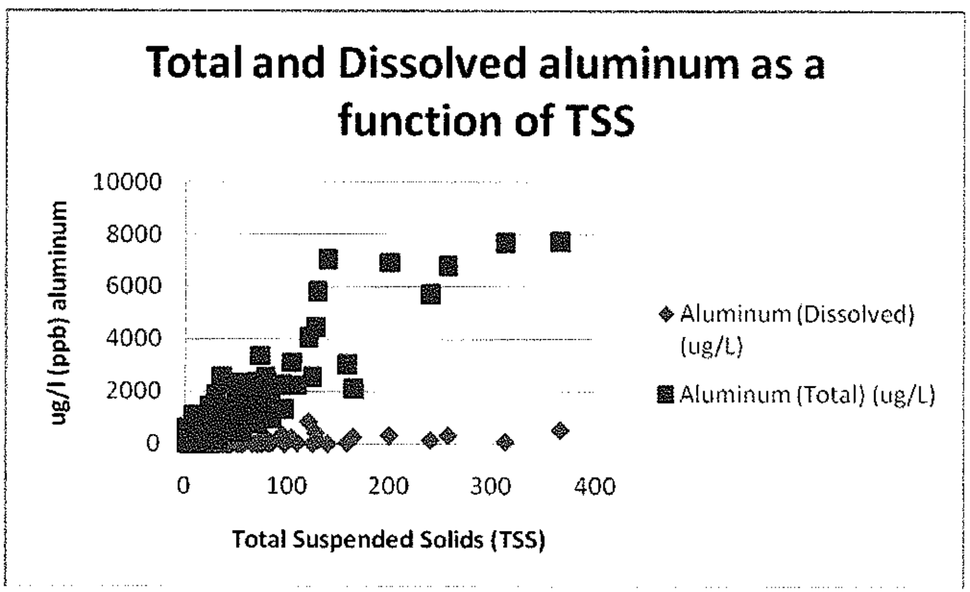
B. Use of Total Aluminum Data

In the listing of aluminum in the 303(d) impaired waters, we object to the use of total aluminum vs dissolved aluminum based on the correlation of total aluminum and total suspended solids and the test method which overstates the amount or organically available aluminum.

Aluminum comprises approximately 7-8% of the earth's crust with some areas have upwards to 30% aluminum. When reviewing the data that IDEM used to determine aluminum concentrations in a particular water body, there was a corresponding increase in total suspended solids (TSS). We believe that there is a direct correlation to the level of aluminum and totals suspended solids as demonstrated by this graph of IDEM's data:



Average values of aluminum for the various values for TSS were plotted to demonstrate a correlation to TSS. Also a plot of total aluminum and dissolved aluminum shows the relation to total suspended solids but no relation to dissolved aluminum.



As cited by Tolpeshta 2007, most aluminum came from lateral runoff, primarily storm water runoff.

The test method for aluminum as stated in Standard Methods states that the sample of wastewater needs to be preserved in nitric acid at a pH<2, then heated on a heat plate until there is approximately 20-30 percent remaining. That test method would yield a result of all aluminum including all aluminum organically bound in the soil. This aluminum would not be released unless the river or stream itself was subjected to these conditions.

Analysis of the data provided by IDEM revealed the following:

- The total aluminum values were estimated 25% of the time and the dissolved aluminum values were estimated 56% of the time.

- Of the total number of values that were above 174 ppb, 18% were estimated.

- If aluminum is assumed to be 7% of the earth's crust based on literature search, then a sample of about 3 ppm of dirt would be sufficient to have 174 ppb of aluminum based on the prescribed test method. Of the 704 samples that exceeded the 174 ppb, 99.3% of those samples also exceeded the 3 ppm for aluminum.

We believe that the total aluminum is directly related to total suspended solids and that is directly related to storm water run-off and not indicative of the true nature of the impairment of the stream. A better measurement for the stream would be total suspended solids but if aluminum is considered a water quality issue, then dissolved aluminum would be better indicator of stream impairment as this aluminum is biologically available to the marine life. The remaining aluminum is really dirt.

III. CONCLUSION

Alcoa believes that the legal and scientific issues identified above need to be addressed before IDEM finalizes its 303(d) list and submits it for U.S. EPA approval. If you have any questions, or would like to meet to discuss these issues further, please feel free to give me a call.

Very truly yours,

Fredric P. Andes /JR

Fredric P. Andes

Enclosures

ATTACHMENT

A

ADVENT
ENVIRON

ALUMINUM AQUATIC LIFE CRITERIA EVALUATION

PHASE II

Prepared for

Jackson Kelly PLLC
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Prepared by

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September 2005

ADVENT
ENVIRON

September 29, 2005

Mr. David Flannery
Jackson Kelly PLLC
1600 Laidley Tower
Charleston, WV 25322

Subject: **Aluminum Aquatic Life Criteria Evaluation – Phase II**
Project No. 2014642A

Dear Mr. Flannery:

ADVENT-ENVIRON is pleased to submit the results of the Phase II efforts evaluating aluminum aquatic life criteria. This work was conducted based on the Phase II Study Plan submitted on April 4, 2005. Among the key study findings were that the USEPA 1988 aluminum criteria database and the additional data obtained in this study are not fully compliant with current data quality guidelines. However, using best professional judgment, some results were deemed acceptable and could be used for re-deriving the acute criterion. As such, no data gaps exist in the revised acute database. None of the chronic data are acceptable for criteria derivation.

Thank you for the opportunity to submit this report. If you have any questions, please contact Scott Hall at (615) 377-4775, extension 154.

Sincerely,

ADVENT-ENVIRON

Scott Hall, Manager
Ecotoxicology Group

Robin Garibay, REM
Principal

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ATTACHMENTS

ALUMINUM AQUATIC LIFE CRITERIA EVALUATION – PHASE II

1.0 BACKGROUND

In 2004, The West Virginia Environmental Quality Board (Board) revised the ambient aluminum water quality criteria for West Virginia waters. As a result, interim aluminum aquatic life criteria (as dissolved aluminum) are 87 µg/L for trout waters and 750 µg/L for all other waters of the State. These criteria will remain in effect until July 4, 2007. The interim criteria provide time for a study to develop aluminum criteria "which are based upon sound science and are protective of aquatic life."

ADVENT-ENVIRON was retained by TRINET to initiate the process of conducting a study to review and update the aluminum aquatic life criteria. The efforts reported herein are based on the Phase II Scope of Work outlined in *Development of Aluminum Aquatic Life Criteria for West Virginia Surface Waters Phase I - Study Plans* (ADVENT, 2005).

2.0 SCOPE OF WORK

Key tasks of the detailed Scope of Work as outlined in the Phase II Study Plan (ADVENT-ENVIRON, 2005) were:

- Validate the data and technical merit of the data used to derive the US Environmental Protection Agency's (USEPA) Ambient Water Quality Criteria (AWQC) for aluminum (USEPA, 1988).
- Conduct a literature search and compile additional aluminum (Al) aquatic toxicity test data published since 1986 (the period through which USEPA compiled data for the AWQC document) and augment the Al AWQC database.
- Identify data gaps and identify potentially sensitive species for which additional testing may be necessary.
- Using toxicity test data meeting the data quality criteria outlined in the Study Plan, determine whether minimum database requirements are met to re-derive Al WQC, and determine the appropriate derivation method (e.g., use of Acute to Chronic Ratios or ACRs).

The report also contains a preliminary review of the "state of the science" regarding the forms[1] of aluminum believed to be most toxic to aquatic life and the water quality conditions altering aluminum toxicity. Likewise, a preliminary review of the analytical methods available to measure various forms of aluminum and their relevance to derivation of water quality criteria is presented.

3.0 METHODS

3.1 Review of USEPA Aluminum Criteria

A review of the 1988 USEPA Al AWQC document (USEPA, 1988) was conducted to determine the basis and validity of the current USEPA ambient freshwater criteria (750 µg/L acute, 87 µg/L chronic, as acid soluble Al) and determine the most sensitive organisms in the database (i.e., those "driving" the criteria). This included obtaining the available published literature referenced in the 1988 USEPA criteria document. The USEPA criteria database was evaluated in accordance with methods and data quality requirements provide by *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses* (USEPA, 1985, referred to here as the 1985 Guidelines), USEPA 40 CFR 132 Appendix A (USEPA, 1995), and ASTM (2004) *Annual Book of ASTM Standards.* These efforts determined whether USEPA criteria are based on sound data, if they were appropriately and correctly calculated, and if the data were correctly interpreted from the original studies.

3.2 Obtain Additional Toxicity Data

The USEPA AQUIRE database was utilized to obtain additional (1987 to present) aluminum toxicity test data for possible use in updated criteria. To ensure a thorough literature search was conducted, additional literature searches were conducted through select on-line journals (e.g., *Environmental Toxicology and Chemistry* and *Canadian Journal of Fisheries and Aquatic Sciences*) and on-line databases such as USGS, US

1 "Form" of aluminum as used in this report refers to an operationally-defined total or dissolved form of aluminum (e.g., 0.45 um filtered for dissolved), whereas "type" of aluminum refers to the type of salt used in a test with aluminum (e.g., sulfate or chloride salt of aluminum).

Fish and Wildlife Service, NTIS (National Technical Information Services), PubMed, OCLC First Search (for Dissertations and Theses), and ABSEARCH. The Water Quality Criteria for Aluminum Technical Appendix (Butcher, 1988) published by Ministry of Environment and Parks Providence of British Columbia was also consulted for additional references. A formal Public Request for Papers was also submitted by the Board (WVEQB, 2005) to obtain any recent research on aluminum aquatic toxicity that may not be in publication. Original references were obtained, where possible, in order to confirm values given in the 1988 Al AWQC document and AQUIRE database. References that could not be obtained because they were either not found or reprints were no longer available included Bringmann, et al,. (1953b), Gibson, (1986), Hennriksen, et al. (1984), Holtz (1983), Muniz et al. (1980), Rosseland (1980), Rosseland et al. (1982), Sparling et al. (1997), Tandjung et al. (1982), and Van Coillie et al. (1983). Attachment 1 contains the full bibliography for this study.

Data Acceptability

ADVENT-ENVIRON evaluated only AQUIRE data with Rank 1 or Rank 2 documentation codes. This documentation coding does not indicate that a particular study meets particular data quality requirements, but reflects the amount of information presented in the paper in order to determine if that particular study does meet data quality requirements. Procedures for determining the AQUIRE ranking are explained in AQUIRE Coding Guidelines (Computer Sciences Corp., 2003) and state the following: "Data encoded are evaluated according to existing standard test methods such as those from the American Society for Testing and Materials (1996), Code of Federal Regulations (1992) and the American Public Health Association (1992)" and "Each publication in the AQUIRE database must [at least] meet the five minimal criteria for acceptance (i.e. chemical, species, concentration, duration and effect)." Based on these minimal criteria and additional criteria from the existing standard test methods listed previously, a documentation code is assigned to each study as "an index of completeness of methods documentation and results presented in the original paper." It is ADVENT-ENVIRON's experience that data ranked 3 or 4 do not contain enough test information to determine if the study meets EPA 1985 Guidance data quality requirements. Therefore, the studies ranked 3 or 4 would not be acceptable for use in criteria calculation.

Acceptable AQUIRE data were then evaluated based on the checklist presented in Attachment 2. This detailed toxicity test data suitability checklist (initially developed by Michigan DEQ and modified by ADVENT-ENVIRON) was used to review all studies, resulting from the literature search, for data acceptability and validity. This checklist reflects USEPA's standards for data validation for developing criteria after issuance of their 1985 Guidelines as well as other testing guidance such as ASTM, GLI, and USEPA acute and chronic whole effluent toxicity testing guidance manuals (USEPA 2002a, 2002b, respectively). USEPA Regions 2, 3, and 5, and the USEPA Office of Research and Development Laboratory in Duluth, Minnesota have used the GLI Guidelines (1990-1996) to refine data quality requirements for criteria derivation. The use of this checklist has been accepted by regulatory agencies. West Virginia regulations (Title 46 Section 1-6, Title 46 Section 1-9) were also consulted for any data quality or procedural requirements associated with criteria derivation (no specific guidance on data quality exists in these West Virginia regulations).

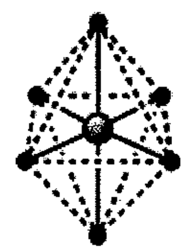
Potentially acceptable data were further evaluated and considered unacceptable if the toxicity test data were generated at pH conditions less than 6.0 and greater than 9.0 s.u. Waters outside this pH range do not meet West Virginia water quality standards (and hence are impaired). Additionally, waters outside of this pH range do not meet current USEPA guidance for toxicity testing (USEPA, 2002a, 2002b). EPA guidance states that mortality due to pH alone may occur if pH is outside the range of 6.0 to 9.0 s.u. It should also be noted that USEPA used toxicity test data from a pH range of 6.5 to 9.0 s.u. for the 1988 aluminum criteria calculation (USEPA, 1988), because the national pH criteria are pH 6.5 to 9.0.

If not enough information or data were presented in the study to determine if data quality requirements were met, it was assumed the requirements were not necessarily met. Instead, study acceptability was determined based on the importance of the missing information (i.e., best professional judgment, or BPJ) to determine data validity. Many references were published prior to USEPA guidelines on refinement to data validity. Therefore, information associated with the study may not have been documented. In addition, particular information needed for data quality determination may have been obtained, but since the focus of a particular study was not generating pure-chemical toxicity data, the information was not necessarily given in the papers.

Data were organized as "acceptable" or "unacceptable" for purposes of AWQC estimation. Water quality parameters (e.g. hardness, pH, alkalinity, and total organic carbon (TOC)) with possible relationships to aluminum toxicity were compiled. Acceptable data were used to determine whether minimum database requirements for criteria derivation were met (USEPA, 1985). Unacceptable data were used to determine trends in species sensitivity to aluminum. It should be noted that although unacceptable data did not meet the stringent data quality requirements necessary for use in deriving AWQC, the data were generally from peer-reviewed or otherwise published sources and are suitable for such trend evaluations.

4.0 RESULTS

4.1 Basic Environmental Aluminum Chemistry



In typical natural waters, if aluminum is not complexed, the aluminum is coordinated by 6 H_20 in an octahedral formation (see figure at right-Al is the central atom, surrounded by the six H_20). Hydrolosis results in progressive loss of hydration shell. Aluminum is relatively insoluble at pH 6 to 8 (Gensemer and Playle, 1999). The solubility of Al is temperature and pH dependant. Aqueous (chemically soluble in water) Al is comprised of Al hydroxyl species and also forms inorganic complexes with F^- and SO_4^{2-} the formation of which vary with water temperature, pH, and ionic strength. Aluminum can also form complexes with organic material (humic and fulvic acids) that result in aluminum being potentially insoluble but remaining suspended within the water column.

Aluminum exists in several states in natural environments, including mononuclear and polynuclear species. Mononuclear species are species whose stoichiometry indicates that only one Al ion is involved in the metal-ligand complex. This refers to complexes that have a 1:1 or 1:2 ratio, examples of which are Al: metal ligand complexes and the Al hydroxyl species (Al^{3+}, $AlOH^{2+}$, etc.). Polynuclear species have multiple aluminum ions in the species as indicated stoichiometrically. Examples include 2:1 and 3:1 ratios, and Al: ligand complexes.

The content of Al in soil ranges from 4 to 14 percent, depending on the amount of clay present. Aluminum is the third most abundant element in nature and comprises about 8% of the earth's crust. Aluminum released by the dissolution of an aluminosilicate (ex. kaolin or kaolinite) will precipitate as amorphous Al $(OH)_3$ (i.e. not readily soluble). In streams, the dissolution of aluminum from clay particles is inhibited because of surface adsorption of strong anions such as NO_3^-, SO_4^{-2}, and PO_4^{-2}. Deprotonated carboxyl groups cause a charge reduction of soluble organic substances. This charge reduction will cause the configuration of the molecule to collapse, reducing its solubility. As these chain-like structures are formed, precipitation increases.

4.2 Determination of Aluminum in Water

Many different types of aluminum occur in water. Srinivasan, et al. (1999) summed it up nicely:

> Total Aluminum is the sum of suspended, colloidal and monomeric aluminum. Particulate Al is the sum of the suspended and colloidal Al. Monomeric Al consists of non-labile, and labile. Non-labile Al is associated with dissolved organic carbon. Labile Al includes aquo (Al^{3+}), and hydroxide, fluoride, and sulphate complexes of Al.

There have been several experimental approaches to determine the levels of various species of aluminum in aqueous samples. Three main approaches have been proposed separately by Driscoll and Letterman (1988), Edzwald and Van Benschoten (1990), and Gardner and Gunn (1991):

- Driscoll and Letterman's procedures separate aluminum into three fractions:
  - Total Reactive Al - determined by acid digestion with HNO_3 at pH 1 for one hour.
  - Total Monomeric Al - determined by simple extraction with 8-hydroxyquinoline in the absence of an acid digestion step.

- Cation-exchange treated monomeric Al (also known as non-labile monomeric Al). Following separation of Total Monomeric Al, a portion is passed through a strongly acidic cation exchange resin. This fraction is the non labile monomeric Al. Labile monomeric Al is determined by subtraction of the total monomeric Al measurement minus the non-labile fraction that passed through the exchange resin.

- Edzwald and Van Benschoten (1990) outlined procedures to isolate five species of Aluminum:

    - Total Reactive Al - determined by one-hour digestion at pH 2.
    - Total Dissolved Al - determined by taking the acid digested fraction and filtering with a 0.22 μM filter.
    - Dissolved Monomeric Al - The total dissolved Al rapidly extracted with 8-hydroxyquinoline to isolate the dissolved monomeric Al fraction.
    - Dissolved Organically bound Al - determined by taking the total dissolved Al fraction and passing it through a column with a strongly acidic cation exchange resin and acidified before analysis.
    - Dissolved Organic Monomeric Al - the non-acidified fraction that passed through the column for determining organically bound Al.

- Gardner and Gunn (1991) have speciated aluminum into four fractions:
    - Total Al – acid digested at pH < 2 s.u.
    - Dissolved Al – filtration through 0.45 μm filter.
    - Low-molecular Weight Al - is found through dialysis through 1000 molecular mass cutoff membrane.
    - Chemically Labile Al - is measured by the speed of reaction with an Al binding agent.

Currently, EPA has approved several methods for the analysis of aluminum in support of the Clean Water Act as outlined in 40 CFR 136. These methods measure total aluminum with dissolved aluminum determined by utilizing these techniques after filtering the sample with a 0.45 micron filter. There are currently no EPA approved methods for the measurement of aluminum fractions (e.g., monomeric aluminum). The EPA approved methods are:

- 200.7 Determination of Metals and Trace Elements in Water and Wastes by Inductively Coupled Plasma-Atomic Emission Spectrometry.
- ASTM D4190-94 - Determination of Metals and Trace Elements in Water and Wastes by Direct Current Plasma.
- ASTM 3500-Al D - Determination of Metals and Trace Elements in Water and Wastes Colorimetetric (Eriochrome cyanine R).
- 200.8 Determination of Trace Elements in Water and Wastes by Inductively Coupled Plasma - Mass Spectrometry (Pending Approval).
- 200.9 Determination of Trace Elements by Stabilized Temperature Graphite Furnace Atomic Absorption Spectrometry (Pending Approval).
- 200.15 Determination of Metals and Trace Elements in Water by Ultrasonic Nebulization Inductively Coupled Plasma-Atomic Emission Spectrometry (Pending Approval).

While much of the above text is useful in understanding the relationship and complexity of aluminum aquatic chemistry and toxicology, the methodologies for direct measurement of specific aluminum species are often complex and not readily available in non-academic settings. Current regulatory guidelines also mandate that total recoverable aluminum, measured using USEPA-approved methodologies, is the form regulated. Total recoverable metals (including aluminum) measurements after filtration are acceptable for NPDES determinations per 40 CFR 122.45c.

4.3 Aluminum Aquatic Toxicology

Conventional toxicology paradigms suggest that the most bioavailable or biologically active (i.e., toxic) forms of chemicals are those in the dissolved phase. This is widely supported by studies dating back to the 1980s (Hamelink, 1980; Schuytema et al., 1983; Hall et al, 1986a, 1986b; USEPA, 2002) and has been further corroborated since that time. Ideally, the active ionic (hence dissolved) form of a metal should best predict its toxicity, but direct measurements for such forms of metal are not routinely conducted. In many cases, dissolved fractions are operationally defined as that portion passing through a 0.45 μm filter (e.g., USEPA, 2002). Hall et al. (1986a, 1986b) demonstrated that it is the dissolved phase of a metal (zinc) and organic compound (chlordane) that is toxic to aquatic organisms. The dissolved phase of these constituents was toxic regardless of the organism's potential modes of exposure (e.g., direct body contact for fish, and direct body contact and ingestion via filter feeding in the case of a daphnid).

The notion that it is the dissolved form of a chemical, especially metals, that is biologically active is also explicit in many of USEPA's allowances for translators (e.g., USEPA, 1996 metals translator guidance) and water effect ratios in regulating the discharge of chemicals. While there may be cases in which ingested particulate forms of chemicals such as those sorbed to particulate matter could be toxic, the preponderance of data demonstrate that it is the dissolved form of a chemical that is able to cross cell membranes that causes toxicity. Thus, it is widely held that for practical purposes (e.g., readily available analytical techniques are available to differentiate forms of a chemical) it is the dissolved form of a constituent that best represents the bio-available/toxic fraction to aquatic life.

There is no known reason to believe that the general mode of aluminum toxicity is different than that of other constituents (i.e., in general, it must be in soluble forms able to cross cell membranes in order to cause toxicity). However, the chemical properties of aluminum dissociation in water confound the conventional approach as more than one chemical form can represent the dissolved fraction over a given pH range. In addition, not all the chemical forms that may represent the dissolved fraction are believed to have equivalent toxicity. Thus, different toxic responses may occur at similar dissolved aluminum concentrations and compromise the ability of dissolved aluminum concentrations to predict toxicological response to aluminum exposure. The amphoteric nature (i.e., more soluble under acidic and basic conditions than neutral conditions, see Stumm and Morgan, 1970; USEPA, 2002) of aluminum is a primary contributor to this complex condition for aluminum.

In addition to the above, there appears to be a general relationship between pH and Al toxicity that shows toxicity to increases as pH decreases. This is consistent with the presumption that the more soluble forms of aluminum that predominate below approximately pH 5.5 are key toxic forms of aluminum. Exceptions to this pattern can be found. For example, dissolved Total Organic Carbon (TOC) would chelate aluminum, maintaining its dissolved form but decreasing its toxicity. Ions such as chloride, fluoride, nitrate, phosphorus, silica, and sulfate also form soluble complexes with Al (USEPA, 1988; Gensemer and Playle, 1999), and the competitive interactions are difficult to predict in terms of toxicological effects. No relationship between Al toxicity and water hardness has been developed by USEPA as they have done in deriving water quality criteria for other metals (see USEPA, 2002).

Consistent with the notion that it is the dissolved form of aluminum that is most toxic, some investigators have specifically suggested that it is monomeric (i.e., 1:1 Al:ligand complexes) aluminum that is most toxic to aquatic life, and Gensemer and Playle (1999) state that measurements of inorganic monomeric Al are probably most meaningful with respect to predicting biological effects. Polynuclear (i.e., 2:1 and higher ratios of Al:ligand complexes) and particulate Al complexes may be less toxic due to their larger size and presumably decreased ability to cross cell membranes.

In conclusion, understanding the relationship between the chemistry and toxicity of Al is very difficult. However, the fundamental principals of aquatic toxicology and the research to date indicate that, like other constituents, dissolved aluminum (so long as not bound to other dissolved constituents that reduce its bioavailability) is generally the most toxic form of aluminum.

4.4 USEPA 1988 Al AWQC Corrections, Data Quality

There are 35 references listed in the USEPA Al AWQC document tables. Thirty-three of these references were obtained and reviewed.[2] Several errors were found in the 1988 Al AWQC document and are listed below.

- Based on a review of the original publication (Brooke et al., 1985), USEPA (1988) incorrectly entered the acute aluminum toxicity test result for *Dugesia*. This test result was corrected from >23,000 µg/L to >16,600 µg/L.
- Since the USEPA 1988 Al criteria document was published, rainbow trout taxonomic classification has been updated. Rainbow trout are now classified in the genus *Oncorhynchus* (not *Salmo* as in 1988). Therefore, rainbow trout are now included in the same genus as Chinook salmon,

2 The Bringmann and Kuhn (1953) and Holtz (1983) references could not be obtained.

which decreases the GMAV for *Oncorhynchus* from > 40,000 µg/L to 20,390 µg/L (before any new acceptable data are added to the database).

- Mistakes were found in Table 2 of the 1988 Al criteria document regarding the chronic data listed:

    - The chronic value for *D. magna* was listed as 742.2 µg/L. According to the original paper, the chronic (28 day test) value should be 1,610 µg/L. It is also noteworthy that the toxicity test had 70 percent control survival, which is below the 80 percent control survival required in USEPA seven day chronic tests (USEPA, 2002b), and below current ASTM toxicity test standards for 21-day chronic daphnid tests (again, a minimum control survival of 80 percent is required for valid tests). Hence, the chronic *D. magna* test used by USEPA is unacceptable.

    - The "chronic limits" (the NOEC and LOEC chronic test endpoints) presented for the fathead minnow are from 2,300 to 4,700 µg/L, resulting in a chronic value of 3,288 µg/L. According to the original reference (Kimball, as listed by USEPA, 1988) the chronic limits for survival should be 7,100 to 11,900 µg/L, and for growth 4,700 to 7,100 µg/L. This changes the chronic values (MATC) to 9,200 µg/L for survival and 5,780 µg/L for growth. EPA 1985 Guidance states that when available, both growth and survival should be taken into account for chronic value calculations. This was not done in the Al criteria document.

- The chronic criterion was not correctly determined. The USEPA's use of the striped bass (Buckler et al., 1987) and brook trout (Cleveland et al., 1986) tests for chronic criterion determination was reviewed. These studies are listed in Table 6 "Unused Data" of the 1988 Al AWQC document because they were determined to be unacceptable for use in criteria calculations. Although a chronic criterion can be lowered to protect an economically important species, these data are not acceptable based on 1985 Guidance data quality guidelines. For chronic criterion calculation, chronic fish data should be based on tests that cover sensitive life stages of that species and for an appropriate duration. For example, 1985 Guidance states that for a partial life-cycle test, the test should begin "with immature juveniles at least two months prior to active gonad development, continue through maturation and reproduction and end not less than 24 days after the hatching of the next generation." The striped bass test (Buckler et al., 1987) duration was only 7 days and began with 160 day old fish. The 1988 chronic criterion was based on the lower chronic limit of the striped bass test. USEPA 1985 Guidance suggests that chronic values be based on the geometric mean of the upper and lower chronic limits or by analyzing chronic data using regression analysis. Therefore, the chronic criterion of 87 µg/L is not appropriate.

  USEPA referenced the brook trout test (Cleveland et al., 1986), as having a statistically significant endpoint of four percent weight reduction compared to the controls. However, this statistical significance was obtained only by virtue of high precision and hence very high statistical power. A decrease of four percent growth weight is not biologically significant. Current USEPA chronic toxicity test guidance uses acceptable Percent Minimum Significant Difference (PMSD) ranges to identify such statistically overly sensitive tests. Based on current guidance, the four percent growth decrease reported by Cleveland et al. (1986) is not meaningful (i.e., an IC25 value, requiring 25 percent effects, could not be obtained). In summary, these chronic tests are not acceptable to use as the basis for the aluminum chronic criterion.

Review of the other studies used to derive the USEPA 1988 Al criteria indicated:

- Using a strict interpretation of the 1985 Guidelines, none of the studies meet all USEPA 1985 data quality requirements. This is primarily due to the fact that one or more major data quality requirements could not be confirmed for all studies.

- Typical study deficiencies included: control performance not given, not enough information was given to determine if dilution water was appropriate (TOC should be <5 mg/L), and grade of test material could not be determined.

- Best professional judgment was used to determine test acceptability, utilizing the critical data quality requirements detailed in Section 4.5.

4.5 Review of Additional Data

From the literature search using AQUIRE, online journals, and other databases mentioned earlier, 169 references were identified, of which 162 were obtained and reviewed.[3]

- Using a strict interpretation of the 1985 Guidelines, none of the studies meet all USEPA 1985 data quality requirements. This is primarily due to the fact that one or more major data quality requirements could not be confirmed for all studies.

- Typical study deficiencies included: control performance not given, not enough information was given to determine if dilution water was appropriate (TOC should be <5 mg/L), and grade of test material could not be determined.

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3 The Gibson (1986), Henricksen et al. (1984), Muniz and Leivestad (1980), Rosseland (1980), Rosseland and Skogheim (1982), Sparling et al. (1997), and Tandjung et al. (1982) references could not be obtained.

- Using best professional judgment to determine test acceptability, the critical data quality requirements are.
    - The type of aluminum tested was a chloride or sulfate salt of aluminum ($AlCl_2$, $Al_2(SO_4)_3$).
    - The toxicity endpoint was clearly defined and appropriate based on the 1985 Guidelines.
    - Test species had reproducing wild populations in North America.
    - The toxicity test was of appropriate duration, and performed on an appropriate life stage of the organism tested.
    - Dilution water was appropriate.
    - Presence of acceptable test controls.
    - The acute values for a species or genus did not differ by more than a factor of 10.

4.6 Revised Acute Database

Table 1 present's acute toxicity test data used in the 1988 Al acute criterion calculation, including the corrected values, and acute data obtained since publication of the Al WQC document. In USEPA guidance on criteria recalculation (USEPA, 1997), toxicity test results can only be deleted from the database based on suspect quality if data of better quality for the same species are substituted for the faulty data. Therefore, all data used in the original criteria document are included unless there was a suitable substitution for a particular data point. The following is a description of the information presented in Table 1:

- Common Name, Genus Species. Data are listed by common name and Genus species of each test organism. The Genus species names listed reflect the current taxonomic classification.
- Type of Al Tested. No references were found that indicated that the use of Al salt (sulfate or chloride) was a concern in terms of an additional toxic response. Given that sulfate and chloride are not toxic to aquatic life until concentrations orders of magnitude above the concentrations of Al necessary to induce toxicity, these types of Al are appropriate for toxicity testing. This is also consistent with the types of chemicals used in derivation of other heavy metals' WQC. It may not be appropriate to use Al toxicity data generated from tests using other compounds of aluminum.

For example, digested aluminum wire is not an appropriate grade of material for toxicity testing. Additionally, Al compounds containing relatively toxic conjugate ions such as ammonia would not be appropriate because it is not known if the cause of toxicity is Al or the toxic conjugate ion. Therefore, given that the toxicities of sulfate and chloride are much lower than Al, tests using either Al sulfate or Al chloride as the test material were considered.

- Toxicity Values. Values are presented as Al. Values as listed in the 1988 Al criteria document, AQUIRE database, and the original referenced paper are listed for each study in Table 1 when available. Toxicity values from all three sources are listed to show possible differences in data interpretation. Toxicity values from the original papers were used for criteria calculations (and in data discussions unless otherwise noted).

- Total or Dissolved Al. Toxicity values are presented as total or dissolved Al. In Table 2, a more specific presentation of total versus dissolved Al toxicity values is available.

- Endpoint. Only toxicity endpoints that are recommended by 1985 Guidance were included in Table 1 for criteria calculation. They include the LC50 value (the lethal concentration to 50 percent of the test organisms in a given time period), the EC50 value (the concentration in which 50 percent of test organisms were effected, e.g. death, impaired mobility, in a given time period), and the TLm value (the mean Tolerance Limit or the concentration of toxicant at which 50 percent of the test organisms survive for a given time period). LD50 values are defined as the Lethal Dose in which 50 percent of test organisms died in a given time period. LD50s are primarily used in terrestrial toxicity testing or in reference to human toxicity, but defines the same effect as an LC50 value.

- Test Duration. Only appropriate test durations as defined by 1985 Guidance are listed. Acute tests with fish, amphipods, and insects are to be 96 hours in duration. Acute tests with cladocerans (water fleas) are to be 48 hours in duration. If recommended test duration was not specified in the 1985 Guidance, ASTM and USEPA Whole Effluent Toxicity (WET) test manuals were consulted.
- Life Stage. Appropriate life stages, as defined in 1985 Guidance, are presented. Tests must be performed on sensitive life stages of the test organism.

- Test Conditions. Test conditions (pH, hardness, temperature, dissolved oxygen, alkalinity, and TOC) are presented for each study. These values reflect either the average of measurements taken during a test, or measurements taken at test initiation or test termination. There was no consistency in what was reported in the original papers. A question mark indicates that particular information was not available.

- <u>Species Resident to WV</u>: It was determined whether the test species listed are residents of West Virginia waters. This was determined by consulting home range maps of the various test organisms, general life history information on the test organisms (i.e., generalists known to be widely distributed were assumed to occur in West Virginia), and consultation with professionals knowledgeable of West Virginia fish and a aquatic invertebrates (this was done in consultation with Mr. Kerry Bledsoe, West Virginia Division of Natural Resources).

- <u>Data Quality Requirements.</u> Whether the paper met all of the 1985 Guidance's data quality requirements or all of the Attachment 2 Checklist data quality requirements was noted. Studies noted with "IN" were missing information in the paper and therefore it could not be determined if the study met all data quality requirements. No study addressed every data quality requirement, and therefore none are considered completely acceptable. However, best professional judgment was used to determine the most critical data quality requirements, and if they were met, the study was included in Table 1. For example, if studies used laboratory control water but did not specifically state a TOC concentration, the TOC concentration was assumed to be less than the requisite 5 mg/L needed to allow data acceptance. Common information missing from these papers are details of dilution waters used, TOC data, whether test organisms were previously exposed to the test material, and the grade of test material used. The Comments column describes some of the issues associated with each study.

4.7 Added Acute Studies

Several acute data points (ASci, 1994; GLEC, 1997) were added to the 1988 Al database and met most of the 1985 Guidance data quality requirements. Although it could not be determined if these studies met all data quality requirements, they were included based on best professional judgment (BPJ). It was determined that these studies should be included in the acute database based on the following:

- It was not stated in the original papers if test organisms were exposed to substantial concentrations of the test material before use in tests, but the organisms were not feral, and came from an in-house culture. (None of the studies that USEPA had included in the 1988 Al database stated if test organisms were pre-exposed to the test material.)

- TOC measurements were not given, but synthetic or laboratory waters were used for dilution water. Synthetic waters typically do not contain TOC concentrations of greater than 5 mg/L. USEPA included in the 1988 Al database tests where the TOC was not known.

- In criteria derivation, USEPA included some data from a given study, but for unknown reasons excluded other data from the same study. If no reason for data exclusion could be determined, all data from the study were added to the database.

With the addition of the new data, the *C. dubia* Genus Mean Acute Value (GMAV) decreased from 2,648 µg/L to 1,757 µg/L. USEPA recalculation procedures state that although selective deletion of a data point previously used in criteria calculations can not be conducted, correcting the database by substituting suspect values with new, more appropriate data for the same species is acceptable. Therefore, the fathead minnow data point of 35,000 µg/L (Kimball, as cited in USEPA 1988) is substituted with several new fathead minnow data points, increasing the GMAV from 35,000 µg/L to 52,154 µg/L. The Kimball study was determined to be unacceptable due to feeding of test organisms during the test. According to USEPA 1985 Guidance, acute tests where organisms were fed should not be used. With the new taxonomic classification of rainbow trout and addition of new data, the GMAV increased from 10,390 µg/L to 19,139 µg/L. Additional brook trout data increased the brook trout GMAV from 3,600 µg/L to 3,980 µg/L. One species, silvery minnow, was added to the acute database.

The Table 1 acute toxicity test data indicate:

- There are no data gaps in the acute database deemed acceptable, therefore, the eight-family minimum requirement for the derivation of an acute criterion is met.

- As expected, no marked differences in aluminum toxicity exist between the types (chloride and sulfate salts) of aluminum added to test solutions. Acute toxicity values (based on the values reported in the original paper) ranged from approximately a few hundred to over 50,000 µg/L Al for both types of Al tested. Based on an evaluation of the toxicity of relatively sensitive organisms such as *Ceriodaphnia*, no differences were evident between the acute toxicity of aluminum added as a sulfate or chloride salt (acute values ranged from 400.9 to 2,704 µg/L Al for sulfate salts, and from 380 to 3,700 µg/L Al for chloride salts).

- There was a difference of greater than 10-fold between acute toxicity values for rainbow trout. The 1985 Guidance (Section IV.H) states the following in regards to inconsistent toxicity test results:

  The agreement of the data within and between species should be considered. Acute values that appear to be questionable in comparison with other acute and chronic data for the same species *and for other species in the same genus probably should not be used in calculation of the Species Mean Acute Value. For example, if the acute values available for a species or genus differ by more than a factor of 10, some or all of the values probably should not be used in calculations.*

The one test conducted with Al sulfate resulted in a total Al acute value of 208.9 µg/L; whereas other tests using Al chloride resulted in acute values of up to 14,600 µg/L Al. This is not likely a response due to the type of Al added, rather, it is likely due to a methodological difference that accounts for the lowest value observed. In contrast to the one low value, there was consistently a higher range of values reported by three different investigators. Therefore, the 208.9 µg/l value for rainbow trout was omitted.

- The *C. dubia* test value of 149.5 µg/L exhibited a 10-fold difference in acute toxicity that was inconsistent with the other data. Per 1985 Guidance this value was also removed from the acute database. Given the very low toxicity of chloride and sulfate the data do not suggest a need to evaluate the data based on the type of salt added to the test solution, and no relationship to the aluminum salt added was observed for any of the 13 other test species.

- The studies that meet data quality guidelines generally did not contain enough information on other water quality parameters (such as silica, sulfate, fluoride, TOC, or suspended solids) to determine a statistical relationship with Al acute toxicity.

- Coldwater fish such as rainbow trout and brook trout tended to be relatively sensitive to aluminum as compared to warmwater fish, but were not the most sensitive organisms tested. There was some discrepancy between data generated for rainbow trout in different studies (toxicity values ranged from approximately 6,170 to over 24,700 µg/L total Al), and between rainbow trout and brook trout. Furthermore, another coldwater fish, the Chinook salmon, was among the least sensitive of the organisms tested (acute toxicity value greater than 40,000 µg/L total Al). With the exception of Chinook salmon, the coldwater fish were more sensitive to Al than the warmwater fish.

- The cladoceran (water flea) *C. dubia* was the most acutely sensitive organism tested based on three studies, and among the most acutely sensitive organism tested based on an additional study. Similar sensitivity was not observed for another cladoceran, *Daphnia magna*, which was among the least sensitive of the organisms tested. Brook trout and rainbow trout were the next most sensitive test organisms. Invertebrates in general were more sensitive to Al than the warmwater fishes, although some benthic (bottom dwelling) invertebrates such as midges were particularly insensitive to Al.

- The revised database contains 33 acute toxicity data points as compared to 16 in the USEPA database. Minimum data set requirements for acute criteria calculation are met.

Based on these assessments, it is concluded that the Table 1 data can be deemed acceptable for use to estimate an updated and re-derived aluminum acute aquatic life criterion.

Table 2 summarizes acute toxicity test data for which total and dissolved aluminum measurements were made and includes both data meeting and not meeting data quality guidelines for criteria derivation. The Table 2 acute toxicity test data indicate:

- The ratio of total to dissolved aluminum acute toxicity values for a given species ranges from 1 to 20 for organisms for which this can be calculated (i.e., no less than values used to calculate ratios).

- The range of acute toxicity values expressed as total Al ranges from less than 138 to 59,100 µg/L, as compared to a range of 7.9 to <1,300 µg/L dissolved Al.

4.8 Chronic Database

Table 3 presents chronic toxicity test data used in the 1988 Al chronic criterion calculation. Table 3 follows the same format as described above for Table 1 with the following clarifications.

- <u>Endpoints.</u> Only chronic endpoints suggested by 1985 Guidance were selected. This includes No Observed Effect Concentration (NOEC), the highest concentration which did not cause an unacceptable adverse effect on any specified biological measurements (e.g., mortality, growth, reproduction); Lowest Observed Effect Concentration (LOEC), the lowest concentration which did cause an unacceptable adverse effect on a specified biological measurement; and the Maximum Acceptable Toxicant Concentration (MATC), the value obtained by calculating the geometric mean of the lower and upper chronic limits (NOEC and LOEC) from a chronic test.

- <u>Test Duration.</u> Only appropriate test durations as defined by 1985 Guidance are listed. Although the striped bass test (Buckler, et al. 1987) duration of seven days is considered inappropriate, it is included in Table 3 because it was used to set the chronic criterion by USEPA in the 1988 Al criteria document.

However, two additional data points, presented in the studies cited by USEPA (1988) but not initially presented by USEPA, were added to the chronic database in order to include data for sub-lethal (growth) endpoints.

None of the additional chronic test data resulting from the literature search meet data quality guidelines nor could be deemed acceptable using best professional judgment. Therefore, the eight-family minimum database requirements specified for chronic criterion calculation are not met. No acceptable ACRs can be calculated with data listed in the chronic database.

4.9 Additional Data

Table 4 summarizes acute and chronic Al toxicity test data that are not of sufficient quality for use in estimating new criteria, or had tests conducted outside the pH range of 6.0 to 9.0 s.u. Although not meeting data quality guidelines for criteria calculation, the Table 4 acute data are useful to confirm some trends identified for the data that do meet data quality guidelines:

- *Ceriodaphnia dubia* and rainbow trout are again the most sensitive test organisms based on selected data.
- Coldwater fish (i.e., rainbow trout, Atlantic salmon, brook trout, brown trout) were again more sensitive to aluminum than warmwater fish (fathead minnow and mosquito fish).
- Frogs (amphibians) appear to be relatively sensitive to Al as evidenced by acute toxicity values ranging from 403 to 811 µg/L total Al. However, this sensitivity may be a function of the low-pH test conditions in these studies (i.e., pH ranged from 4.5 to 4.8 s.u.). Based on only the lowest reported toxicity value for each species, the leopard frog's apparent sensitivity is surpassed only by *C. dubia* and rainbow trout.

The Table 4 chronic data indicate[4]:

4 These data do not meet data quality Guidelines, and results based on more suitable data may indicate different results.

- Organisms with chronic values of less than 100 µg/L were Atlantic salmon (three of four chronic values less than 80 µg/L and as low as 33 µg/L total Al), and the narrow-mouthed toad (chronic value 50 µg/L total Al). Rainbow trout had chronic values as low as 75 µg/L total Al, while others were over 5,000 µg/L total Al. This is consistent with species sensitivity trends observed for acute toxicity.

- Organisms with chronic values less than 300 µg/L total Al were goldfish, largemouth bass, and brook trout. The similar sensitivities of the two warmwater fish to the cold water brook trout is different than observed for acute tests.

- The inorganic monomeric Al value for Atlantic salmon (78 µg/L), although among the lowest values in the Table 4 database, was not the lowest value for this organism. This indicates that inorganic monomeric Al may not be the sole toxic form of aluminum to this test species.

- The high values for rainbow trout (greater than 5,000 µg/L total Al) confound comparisons between warmwater and coldwater fish. Nonetheless, the other Table 4 data do not indicate a higher sensitivity for coldwater fish. For example, the chronic values for Atlantic salmon range from 33 to 402 µg/L, and from 283 to over 300 µg/L for brook trout. This compares to values of 70 to 170 µg/L total Al for warmwater fish such as goldfish, largemouth bass, and three-spined stickleback.

- While some chronic tests indicate green algae to be relatively sensitive to Al (chronic values of 170 to 630 µg/L total Al), other studies showed toxicity values ranging from 4,000 to 108,000 µg/L.

Attachment 3 presents other data that could not be used for criteria derivation due to unacceptable endpoints, such as percent mortality and time to 50 percent test organism mortality. Reasons studies were considered unacceptable include:

- Did not include a control treatment or specify control performance.
- Test material, duration, or tested life stage not appropriate.
- Dilution water not appropriate.
- Test endpoint not appropriate.

5.0 CONCLUSIONS AND RECOMMENDATIONS

- The USEPA 1988 AWQC databases and the additional data recently obtained are not fully compliant with data quality guidelines as defined by the checklist used for this study.

- Using best professional judgment (BPJ) based on critical data quality elements (e.g., life stage, test duration, test endpoint), some results were deemed acceptable, and could be used for re-deriving the acute criterion. As such, no data gaps exist in the revised acute database.

- Using BPJ, based on critical data quality elements, no results were deemed acceptable for use in defining ACRs or in re-deriving the chronic criterion.

- None of the chronic data are acceptable for criteria derivation. Thus, an 8-family data gap exists for calculating a chronic criterion by such means. Alternatively, a 3 or 4 species (i.e., the most sensitive species) data gap exists if the ACR approach is taken to criteria derivation.

The following options are available for developing a chronic criterion:

- Conducting the full 8-family minimum database approach, or
- Develop chronic data and corresponding ACRs for a minimum of three sensitive species.

6.0 REFERENCES

ADVENT, 2005. Development of Aluminum Aquatic Life Criteria for West Virginia Surface Waters Phase I - Study Plans. The ADVENT Group, Inc., Brentwood, Tennessee. April 4, 2005.

ASci Corporation/ASci Duluth. 1994. Aluminum Water-Effect Ratio for the 3M Middleway Plant Effluent Discharge Middleway, West Virginia.

ASTM (American Society for Testing and Materials), 2004. Annual Book of ASTM Standards – Environmental Assessment, Hazardous Substances and Oil Spill Response, Waste Management. Vol. 11.04. ASTM. Philadelphia, PA.

Besser, J.M., W.G. Brumbaugh, C.D. Ivey, D.R. Buckler, and C.G. Ingersoll. 2003. Effects of Calcium and Equilibration Time on the Toxicity of Aluminum to Brook Trout and Rainbow Trout. In Preceedings of Society of Environmental Toxicology and Chemistry 24th Annual Meeting Austin, TX 2003.

Brooke, L. 1985. University of Wisconsin-Superior. Superior. WJ. (Memorandum to C. Stephan. U.S. EPA. Duluth, MN. July 25.)

Buckler, D., P.M. Mehrle, R. L. Cleveland, and F.J. Dwer. 1987. Influence of pH on the Toxicity of Aluminum and Other Organic Contaminants to East Coast Striped Bass. Water, Air, Soil Poll., 35: 97-106.

Buckler, D.R., L. Cleveland, E.E. Little, and W.G. Brumbaugh. 1995. Survival, Sublethal Responses, and Tissue Residues of Atlantic Salmon Exposed to Acidic pH and Aluminum. Aquat.Toxicol. 31(3): 203-216.

Butcher, G.A. 1988. Water Quality Criteria for Aluminum Technical Appendix. Ministry of Environment and Parks Province of British Columbia. Water Quality Unit.

Call, D.J., L.T. Brooke, C.A. Lindberg, T.P. Markee, D.J. McCauley and S.H. Poirier. 1984. Toxicity of Aluminum to Freshwater Organisms in Water of pH 6.5 to 8.5. Univ. of Wisconsin-Superior, Centre for Lake Superior Environmental Studies, Tech. Report (549-238-RT-WRD).

Cleveland, L., E.E. Little, S.J. Hamilton, D.R. Buckler and J.B. Hunn. 1986. Interactive Toxicity of Aluminum and Acidity to Early Life Stages of Brook Trout. Trans. Am. Fish. Soc. 115: 610-620.

Computer Sciences Corp. 2003. ECOTOX ECOTOXicology Database System AQUIRE Coding Guidelines. Prepared for USEPA by Computer Sciences Corp. 56 pp.

Courtijn, E., C. Vandecasteele, and R. Dams. 1990. Speciatoin of Aluminum in Surface Water. Sci. Tot. Envt.

Freda, J., V. Cavdek, and D.G. McDonald. 1990a. Title: Role of Organic Complexation in the Toxicity of Aluminum to Rana pipiens Embryos and Bufo americanus Tadpoles. Can. J. Fish. Aquat. Sci. 47: 217-224.

Freda, J., and D.G. MCDonald. 1990b. Effects of Aluminum on the Leopard Frog, Rana pipiens: Life Stage Comparisons and Aluminum Uptake. Can. J. Fish. Aquat. Sci, 47: 210-216.

Gensemer, R. W. and R. C. Playle. 1999. The Bioavailability and Toxicity of Aluminum in Aquatic Environments. Crit. Rev. in Envtl. Sci. Technol. 29 (4): 315-450.

GLEC (Great Lakes Environmental Center). 1997. Report: Water-Effect Ratio Determination for Aluminum at Fly Ash Run. In Support of the Development of Site-Specific Criteria at the Albright Power Station Ash Disposal Site Albright, West Virginia.

Gostomski, F. 1990. The Toxicity of Aluminum to Aquatic Species in the US. Geochem. Health. 12, pp. 51to 54.

Hall, W.S., Dickson, K.L., Saleh, F.Y., and J. Rodgers, Jr. 1986a. Effects of Suspended Solids on the Bioavailability of Chlordane to Daphnia magna. Arch. Env. Contam. Toxicol. 37:308-316.

Hall, W.S., Dickson, K.L., Saleh, F.Y., Rodgers, J.H. Jr., Wilcox, D. and Entezami, A. 1986b. Effects of Suspended Solids on the Acute Toxicity of Zinc to Daphnia magna and Pimephales promelas. Wat. Res. Bull. 22 (6) 913-920.

Hamelink, J.L., 1980. Bioavailability of Chemicals in Aquatic Environments. In: Biotransformation and Fate of Chemicals in Aquatic Environments. A.W. Maki, K.L. Dickson, and J. Cairns Jr., Eds. Ann Arbor Science Publishers. Ann Arbor, MI. 150 p.

Havas, M. 1985. Aluminum bioaccumulation and toxicity to Daphnia magna in soft water at low pH. Can.J. Fish. Aquat. Sci. 42:1741-1748.

Henry, T.B., E.R. Irwin, J.M. Grizzle, W.G. Brumbaugh, and M.L. Wildhaber. 2001. Gill Lesions and Death of Bluegill in an Acid Mine Drainage Mixing Zone. Env. Toxico. Chem. Vol. 20. No. 6. pp. 1304 to 1311.

Hunter, J.B., S.F. Ross, and J. Tannahill. 1980. Aluminum Pollution and Fish Toxicity. Water Pollut. Control 79: 413-420.

McCahon, C.P, and D. Pascoe. 1989. Short-term Experimental Acidification of a Welsh Stream: Toxicity of Different Forms of Aluminum to at Low pH to Fish and Invertebrates. Arch. Env. Contam. Toxicol. 18: 233 – 242.

Neville, CM. 1985. The Physiological Response of Juvenile Rainbow Trout, Salmo gairdneri, to Acid and Aluminum - Prediction of Field Responses From Laboratory Data. J. Can. Fish. Aquat. Sci. 42: 2004-2019.

Nordrstrom, D.K. and H.M. May. 1996. Aqueous Equilbrium Data for Mononuclear Aluminum Species. In: The Environmental Chemistry of Aluminum (2nd Ed.). pp 39 to 80. (G. Sposido, Ed.). CRC Press. Boca Raton, FL.

Odonnell, A.R., G. Mance, and R. Norton. 1984. A Review of the Toxicity of Aluminum in Fresh Water. WRC Environment, Medmenham Laboratory England. Technical Report TR197, 27 p.

Reash, R.J., R.E. Lockwood, J.G. Belviso. 2003. Toxicity Identification Evaluation of a Coal Ash Effluent: Assessment of Watershed Mine Drainage Influence. Proceedings of Society of Environmental Toxicology and Chemistry 24th Annual Meeting. Austin, TX.

Schuytema, G.S., P.O. Nelson, K.W. Malueg, A.Y. Nebeker, D.F. Krauczyk, A.K. Ratcliff, and J.H. Gakstatter. 1983. Toxicity of Cadmium in Water and Sediment Sluries to Daphnia magna. Env. Tox. Chem. 3:293 to 308.

Soucek, D.J., D.S. Cherry, and C.E. Zipper. 2001. Aluminum-dominated Acute Toxicity to the Cladoceran Ceriodaphnia dubia in Neutral Waters Downstream of an Acid Mine Drainage Discharge. Can. J. Aquat. Sci. 58: 2396-2404.

Stumm, W and J.J. Morgan. 1970 Aquatic Chemistry – An Introduction Emphasizing Chemical Equilibria in Natural Waters. Wiley-Interscience. New York, New York.

USEPA, 1985. Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses. EPA/822-R-85-100. Office of Water. Washington, DC.

USEPA, 1988. Ambient Water Quality Criteria for Aluminum – 1988. EPA 440/5-86-008. USEPA Office of Water Regulations and Standards. Criteria and Standards Division. Washington, DC.

USEPA, 1995. USEPA 40 CFR 132 Appendix A. Final Water Quality Guidance for the Great Lakes System; Final Rule.

USEPA, 1996. The Metals Translator: Guidance for Calculating a Total Recoverable Permit Limit from a Dissolved Criterion. EPA 823-B-96-007. June 1996. Office of Water. Washington, DC.

USEPA, 1997. Modifications to Guidance Site-Specific Criteria. Memorandum clarifying the Recalculation Procedure. To: EPA Water Quality Branch Chiefs and Water Quality Coordinators, From: Jeanette Wiltse, Director of Health and Ecological Criteria Division. December 3, 1997. Office of Water. Washington, DC.

USEPA, 2002a. Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms – Fifth Edition. EPA-821-R-02-012. USEPA Office of Water. Washington, D.C.

USEPA, 2002b. Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms – Fourth Edition. EPA-821-R-02-013. USEPA Office of Water. Washington, D.C.

USEPA, 2002c. National Recommended Water Quality Criteria: 2002. EPA-822-R-02-047. USEPA Office of Water, Office of Science and Technology. Washington, D.C.

WVEQB (West Virginia Environmental Quality Board), 2005. Notice of West Virginia EQB, Request for Data. 22 WV Reg. 26 (April 15, 2005).

TABLE 1. ALUMINUM ACUTE TOXICITY DATABASE

Common Name	Genus Species	Form Of Aluminum Tested	Toxicity Value as Al – Value Reported In: EPA 1988 (µg/L)	AQUIRE (µg/L)	Paper (µg/L)	Toal or Dissolved[1]	Endpoint	Duration	Life Stage	Test Conditions: pH (s.u.)	Hardness (mg/l)	Temp (deg C)	D.O. (mg/L)	Alkalinity (mg/L)	TOC (mg/L)	References	Species Resident To WV?
Cladoceran	*Ceriodaphnia dubia*	$AlCl_3$	-	-	380	total	LC50	48 hr	< 24 hr	7.7	48	25	8.1	32	?	GLEC WER Fly Ash, 1997	Y
Cladoceran	*Ceriodaphnia dubia*	$AlCl_3$	-	-	420	total	LC50	48 hr	< 24 hr	7.7	48	25	7.6	32	?	GLEC WER Fly Ash, 1997	Y
Cladoceran	*Ceriodaphnia dubia*	$AlCl_3$	-	-	520	total	LC50	48 hr	< 24 hr	7.5	40	25	7.9	30	?	GLEC WER Fly Ash, 1997	Y
Cladoceran	*Ceriodaphnia dubia*	$AlCl_3$	1,900	1,900	1,900	total	EC50	48 hr	< 24 hr	7.4	50	25	7.00	46	?	McCauley et al 1986	Y
Cladoceran[2]	*Ceriodaphnia dubia*	$AlCl_3$	-	2,560	2,560	total	EC50	48 hr	< 24 hr	8.13	50	25	7.40	46	?	McCauley et al 1986	Y
Cladoceran	*Ceriodaphnia dubia*	$Al_2(SO_4)_3$	-	-	2,704	total	LC50	48 hr	< 24 hr	8.0	320-350	20	?	?	< 5	ASci Al WER for 3M, 1994	Y
Brook Trout	*Salvelinus fantinalis*	$Al_2(SO_4)_3$	3,600	3,600	3,600	total	LD 50	96 hr	juvenile	6.5	?	11	?	?	?	Decker and Menendez 1974	Y
Cladoceran	*Ceriodaphnia sp.*	$AlCl_3$	3,690	3,690	3,690	total	LC50	48 hr	< 24 hr	7.68	47.4	23.2-25	8.1-8.3	41.6	?	Call 1984	Y
Brook Trout	*Salvelinus fantinalis*	$Al_2(SO_4)_3$	-	4,450	4,400	total	LD 50	96 hr	juvenile	6.0	?	11	?	?	?	Decker and Menendez 1974	Y
Rainbow Trout	*Oncorhynchus mykiss*	$AlCl_3$	7,400	7,400	7,400	total	LC50	96 hr	juvenile	6.59	47.4	15.9-17.8	8.7	41.6	?	Call 1984	Y
Rainbow Trout	*Oncorhynchus mykiss*	$AlCl_3$	14,600	14,600	14,600	total	LC50	96 hr	juvenile	7.31	47.4	15.9-16.3	9.4	41.6	?	Call 1984	Y
Amphipod	*Gammarus pseudolimnaeus*	$AlCl_3$	22,000	NR	22,000	total	LC50	96 hr	adult?	7.53	47.4	17.4-16.7	9.4	41.6	?	Call 1984	Y
Snail	*Physa sp.*	$AlCl_3$	30,600	30,600	30,600	total	LC50	96 hr	adult?	7.55	47.4	16.9-17.5	?	41.6	?	Call 1984	Y
Fathead minnow	*Pimephales promelas*	$Al_2(SO_4)_3$	35,000	NR	35,000	?	LC 50	96 hr	juvenile	7.34	220	24.5	6.28	233	?	Kimball manuscript	Y
Cladoceran	*Daphnia magna*	$Al_2(SO_4)_3$	38,200	36,200	38,200	?	LC 50	48 hr	< 24 hr	7.05	220	20.1	6.08	?	?	Kimball manuscript	Y
Midge	*Tanytarsus dissimilis*	$Al_2(SO_4)_3$	>79,000	NR	75,700	total	LC50	96 hr	2nd. 3rd instar	6.85-7.71	17.43	20	5.5	?	?	Lamb and Bailey 1981	Y
Chinook salmon	*Oncorhynchus tshawytscha*	$NaAlO_2$	>40,000	NR	> 40,000	total	TLm	96 hr	juvenile	7.0	26	10	8-9	?	?	Peterson et al 1974	N
Silvery minnow	*Hybognathus amarus*	$AlCl_3$	-	NR	> 59,100 / > 1,300	total / diss	LC50	96 hr	3-5 dph	8.1	148	25	> 75 % sat.	128	?	Buhl 2002	N
Fathead minnow	*Pimephales promelas*	$AlCl_3$	-	NR	> 59,100 / > 1,300	total / diss	LC50	96 hr	4-6 dph	8.1	148	25	> 75 % sat.	128	?	Buhl 2002	Y
Planarian	*Dugesia tigrina*	$AlCl_3$	>23,000	NR	>16,600	total	LC50	96 hr	adult	7.48	47.4	22-24.5	?	43.1	?	Brooke et al 1985	Y
Stonefly	*Acroneuria sp.*	$AlCl_3$	>22,600	22,600	>22,600	total	LC50	96 hr	nymph	7.46	47.4	16.3-16.6	9.7	41.6	?	Call 1984	Y
Rainbow Trout[2]	*Oncorhynchus mykiss*	$AlCl_3$	>24,700	24,700	>24,700	total	LC50	96 hr	juvenile	8.17	47.4	16.0-18.5	8.6	41.6	?	Call 1984	Y
Channel catfish	*Ictalurus punctatus*	$AlCl_3$	>47,900	NR	>47,900	total	LC50	96 hrs	yoy	7.54	47.4	16.5-16.9	8.9	41.6	?	Call 1984	Y
Fathead minnow[2]	*Pimephales promelas*	$AlCl_3$	>48,200	-	>48,200	total	LC50	96 hr	32-33 d old	7.5	47.4	22.9	8.1	41.6	?	Call 1984	Y
Yellow perch	*Perca flavescens*	$AlCl_3$	>49,800	49,800	>49,800	total	LC50	96 hrs	yoy	7.55	47.4	16.4-16.9	9.8	41.6	?	Call 1984	Y
Fathead minnow[2]	*Pimephales promelas*	$AlCl_3$	>49,800	-	>49,800	total	LC50	96 hr	32-33 d old	8.2	47.4	22.9	8.1	41.6	?	Call 1984	Y
Green sunfish	*Lepomis cyanellus*	$AlCl_3$	>50,000	50,000	>50,000	total	LC50	96 hrs	3 mon. old	7.55	47.4	20.9-22.6	9.1	41.6	?	Call 1984	Y
Cladoceran	*Ceriodaphnia dubia*	$Al_2(SO_4)_3$	-	-	400.9 / 34.45	total / diss	LC50	48 hr	< 24 hr	7.5	40-50	20	?	?	< 5	ASci Al WER for 3M, 1994	Y
Cladoceran	*Ceriodaphnia dubia*	$Al_2(SO_4)_3$	-	-	537.7 / 154.4	total / diss	LC50	48 hr	< 24 hr	7.5	40-50	20	?	?	< 5	ASci Al WER for 3M, 1994	Y
Rainbow Trout	*Oncorhynchus mykiss*	$AlCl_3$	-	6,170 / 570	6,170 / 570	total / diss	LC50	96 hr	juvenile	8.3	23.2	14	?	?	?	Gundersen et al. 1994	Y
Rainbow Trout	*Oncorhynchus mykiss*	$AlCl_3$	-	6,170 / 610	6,170 / 610	total / diss	LC50	96 hr	juvenile	8.3	35	14	?	?	?	Gundersen et al. 1994	Y
Rainbow Trout	*Oncorhynchus mykiss*	$AlCl_3$	-	6,930 / 670	6,930 / 670	total / diss	LC50	96 hr	juvenile	8.3	115.8	14	?	?	?	Gundersen et al. 1994	Y
Rainbow Trout	*Oncorhynchus mykiss*	$AlCl_3$	-	7,670 / 730	7,670 / 730	total / diss	LC50	96 hr	juvenile	8.3	83.6	14	?	?	?	Gundersen et al. 1994	Y

Notes:
Data used in EPA 1988 calculation
? = information not found in original paper
TLm = tolerance limit
dph = days post hatch
NR = not reported
NI = Not enough information in paper
to determine if requirement was met

1. Dissolved samples filtered through 0.4 or 0.45 um filter.
2. USEPA did not use these studies for criteria calculations.
If tests were conducted properly, ">" values should be used (USEPA 1985)

TABLE 1. ALUMINUM ACUTE TOXICITY DATABASE

Common Name	Genus Species	Paper Meets EPA 1985 Guidelines	Paper Meets All Checklist Requirements	Comments
Cladoceran	*Ceriodaphnia dubia*	NI	NI	TOC info not given, but used recon lab water. Measured test conc. at test initiation only
Cladoceran	*Ceriodaphnia dubia*	NI	NI	TOC info not given, but used recon lab water. Measured test conc. at test initiation only
Cladoceran	*Ceriodaphnia dubia*	NI	NI	TOC info not given, but used recon lab water. Measured test conc. at test initiation only
Cladoceran	*Ceriodaphnia dubia*	NI	NI	Raw lake superior water used for dilution water photoperiod not specified, organism pre-exposure not specified
Cladoceran[2]	*Ceriodaphnia dubia*	NI	NI	Raw lake superior water used for dilution water, photoperiod not specified, organism pre-exposure not specified
Cladoceran	*Ceriodaphnia dubia*	NI	NI	Not specified if test organisms were previously exposed to conc. of test material (lab culture)
Brook Trout	*Salvelinus fontinalis*	NI	NI	AQUIRE had these listed under iron salt, grade of test material not known, carbon filtered tap water used for dilution water, control had 0.07 mg/L Al organism pre-exposure not specified
Cladoceran	*Ceriodaphnia sp.*	NI	NI	Unprocessed lake water used for dilution water, TOC?, organism pre-exposure not specified
Brook Trout	*Salvelinus fontinalis*	NI	NI	AQUIRE had these listed under iron salt, grade of test material not known, control had 0.96 mg/L Al, carbon filtered tap water used for dilution water, organism pre-exposure not specified
Rainbow Trout	*Oncorhynchus mykiss*	NI	NI	Unprocessed lake water used for dilution water. TOC?, organism pre-exposure not specified
Rainbow Trout	*Oncorhynchus mykiss*	NI	NI	Unprocessed lake water used for dilution water. TOC?, organism pre-exposure not specified
Amphipod	*Gammarus pseudolimnaeus*	NI	NI	Unprocessed lake water used for dilution water. TOC?, organism pre-exposure not specified
Snail	*Physa sp.*	NI	NI	AQUIRE had this listed under ammonium chloride, unprocessed lake water used for dilution water. TOC? organism pre-exposure not specified
Fathead minnow	*Pimephales promelas*	N	NI	Fish were fed during test, well water used for dilution water, TOC?, organism pre-exposure not specified
Cladoceran	*Daphnia magna*	NI	NI	Well water used for dilution water, organism pre-exposure not specified
Midge	*Tanytarsus dissimilis*	NI	NI	Dilution water was filtered lake water no info on feeding, control performance, Dissolved Al = <0.1ug/L for all alum concentrations, organism pre-exposure to test material not specified
Chinook salmon	*Oncorhynchus tshawytscha*	NI	NI	Control performance, age of organisms, feeding not known, test temp not appropriate, dilution water = carbon filtered tap
Silvery minnow	*Hybognathus amarus*	NI	NI	Grade of test material not given, TOC info not given, but used recon water
Fathead minnow	*Pimephales promelas*	NI	NI	Grade of test material not given, TOC info not given, but used recon water
Planarian	*Dugesia tigrina*	NI	NI	Lake Superior water used for dilution water, controls, TOC?, organism pre-exposure not specified
Stonefly	*Acroneuria sp.*	NI	NI	Unprocessed lake water used for dilution water, TOC?, organism pre-exposure not specified
Rainbow Trout[2]	*Oncorhynchus mykiss*	NI	NI	Insufficient mortalities occurred for LC50 determination, unprocessed lake water used for dilution water
Channel catfish	*Ictalurus punctatus*	NI	NI	Uunprocessed lake water used for dilution water, TOC?, organism pre-exposure not specified
Fathead minnow[2]	*Pimephales promelas*	NI	NI	Insufficient mortalities occurred for LC50 determination, unprocessed lake water used for dilution water, organism pre-exposure not specified
Yellow perch	*Perca flavescens*	NI	NI	AQUIRE had this listed under ammonium chloride, unprocessed lake water used for dilution water. TOC? organism pre-exposure not specified
Fathead minnow[2]	*Pimephales promelas*	NI	NI	Insufficient mortalities occurred for LC50 determination, unprocessed lake water used for dilution water, organism pre-exposure not specified
Green sunfish	*Lepomis cyanellus*	NI	NI	AQUIRE had this listed under ammonium chloride, unprocessed lake water used for dilution water. TOC? organism pre-exposure not specified
Cladoceran	*Ceriodaphnia dubia*	NI	NI	Not specified if test organisms were previously exposed to conc. of test material (lab culture)
Cladoceran	*Ceriodaphnia dubia*	NI	NI	Not specified if test organisms were previously exposed to conc. of test material (lab culture)
Rainbow Trout	*Oncorhynchus mykiss*	NI	NI	Grade of test material not given, TOC info not given, but used recon well water
Rainbow Trout	*Oncorhynchus mykiss*	NI	NI	Grade of test material not given, TOC info not given, but used recon well water
Rainbow Trout	*Oncorhynchus mykiss*	NI	NI	Grade of test material not given, TOC info not given, but used recon well water
Rainbow Trout	*Oncorhynchus mykiss*	NI	NI	Grade of test material not given, TOC info not given, but used recon well water

Notes:
Data used in EPA 1988 calculation
? = Information not found in original paper
TLm = tolerance limit
dph = days post hatch
NR = not reported
NI = Not enough information in paper
to determine if requirement was met

1. Dissolved samples filtered through 0.4 or 0.45 um filter.
2. USEPA did not use these studies for criteria calculations.
If tests were conducted properly, ">" values should be used (USEPA 1985)

TABLE 2. ALUMINUM TOXICITY ASSOCIATED WITH DISSOLVED ALUMINUM AND FILTER SIZE

Common Name	Genus Species	Form Of Aluminum Tested	Tox Value		Ratio Total to Dissolved	Filter Size Used	Endpoint	Duration	Life Stage	Test Conditions			Reference
			Total (µg/L)	Dissolved (µg/L)						pH (s.u.)	Hardness (mg/l)	Temp (deg C)	
Fathead minnow	*Pimephales promelas*	$AlCl_3$	>59,100	>1,300	N/A	0.4 um	LC50	96 hr	4-6 dph	8.1	148	25	Buhl 2002
Silvery minnow	*Hybognathus amarus*	$AlCl_3$	>59,100	>1,300	N/A	0.4 um	LC50	96 hr	3-5 dph	8.1	148	25	Buhl 2002
Rainbow Trout	*Oncorhynchus mykiss*	$AlCl_3$	6,170	570	11	0.4 um	LC50	96 hr	juvenile	8.3	23.2	14	Gundersen et al. 1994
Rainbow Trout	*Oncorhynchus mykiss*	$AlCl_3$	6,170	610	10	0.4 um	LC50	96 hr	juvenile	8.3	35	14	Gundersen et al. 1994
Rainbow Trout	*Oncorhynchus mykiss*	$AlCl_3$	7,670	730	11	0.4 um	LC50	96 hr	juvenile	8.3	83.6	14	Gundersen et al. 1994
Rainbow Trout	*Oncorhynchus mykiss*	$AlCl_3$	6,930	670	10	0.4 um	LC50	96 hr	juvenile	8.3	115.8	14	Gundersen et al. 1994
Rainbow Trout	*Oncorhynchus mykiss*	$Al_2(SO_4)_3$	208.9	24.5	9	0.45 um	LC50	96 hr	fry	7.5	40-50	12	ASci Al WER for 3M, 1994
Cladoceran	*Ceriodaphnia dubia*	$Al_2(SO_4)_3$	150	26.4	6	0.45 um	LC50	48 hr	< 24 hr	6.5	7.5	20	ASci Al WER for 3M, 1994
Cladoceran	*Ceriodaphnia dubia*	$Al_2(SO_4)_3$	156	7.9	20	0.45 um	LC50	48 hr	< 24 hr	6.5	7.5	20	ASci Al WER for 3M, 1994
Cladoceran	*Ceriodaphnia dubia*	$Al_2(SO_4)_3$	401	34.5	12	0.45 um	LC50	48 hr	< 24 hr	7.5	40-50	20	ASci Al WER for 3M, 1994
Cladoceran	*Ceriodaphnia dubia*	$Al_2(SO_4)_3$	538	154	3	0.45 um	LC50	48 hr	< 24 hr	7.5	40-50	20	ASci Al WER for 3M, 1994
Cladoceran	*Ceriodaphnia dubia*	$Al_2(SO_4)_3$	<138	<23.5	6	0.45 um	LC50	48 hr	< 24 hr	6.5	7.5	20	ASci Al WER for 3M, 1994
Brook Trout	*Salvelinus fantinalis*	$AlCl_3$	1,370	285	5	0.45 um	LC 50	96 hr	juvenile	5.4	40.7	12	Besser et al 2003
Brook Trout	*Salvelinus fantinalis*	$AlCl_3$	296	225	1	0.45 um	LC 50	96 hr	juvenile	5.3	117	12	Besser et al 2003
Brook Trout	*Salvelinus fantinalis*	$AlCl_3$	213	160	1	0.45 um	LC 50	96 hr	juvenile	5.3	111	12	Besser et al 2003
Brook Trout	*Salvelinus fantinalis*	$AlCl_3$	1,280	208	6	0.45 um	LC 50	96 hr	juvenile	5.3	?	12	Besser et al 2003
Rainbow Trout	*Oncorhynchus mykiss*	$AlCl_3$	1,240	214	6	0.45 um	LC 50	96 hr	juvenile	5.4	40.7	12	Besser et al 2003
Rainbow Trout	*Oncorhynchus mykiss*	$AlCl_3$	225	203	1	0.45 um	LC 50	96 hr	juvenile	5.3	117	12	Besser et al 2003

Note:
dph = days post hatch

TABLE 3. ALUMINUM CHRONIC TOXICITY DATABASE

COMMON NAME	GENUS SPECIES	FORM OF ALUMINUM TESTED	TOXICITY VALUE: VALUE REPORTED IN[a] EPA 1988 (µg/L)	AQUIRE (µg/L)	PAPER (µg/L)	Total or Dissolved	Endpoint	Duration	Life Stage	Test Conditions: pH (a.u.)	Hardness (mg/l)	Temp (deg C)	D.O. (mg/L)	Alkalinity (mg/L)	TOC (mg/L)	Reference	Paper Meets EPA 1985 Guidelines	Paper Meets All Checklist Requirements
Cladoceran	*Ceriodaphnia dubia*	$AlCl_3$	1,908	1,900	1,908	total	MATC	7 d	< 16 hr	7.15	50	25	7.1	46	?	McCauley et al 1986	NI	N
Cladoceran	*Daphnia magna*	$Al_2(SO_4)_3$	742	-	1,010	total	LC50	28 d	< 24 hr	8.3	250	19.0	7.81	211	?	Kimball manuscript	N	N
Fathead minnow	*Pimephales promelas*	$Al_2(SO_4)_3$	3,288	NR	4,700 / 7,100	?	NOEC/LOEC growth	28 d	eggs	7.27	230	24.8	6.98	233	?	Kimball manuscript	NI	N
Fathead minnow	*Pimephales promelas*	$Al_2(SO_4)_3$	3,288	NR	7,100 / 11,900	?	NOEC/LOEC survival	28 d	eggs	7.27	220	24.8	6.98	233	?	Kimball manuscript	NI	N
Striped Bass	*Marone saxatilis*	$Al_2(SO_4)_3$	174.4	-	87.2/174.4	total	NOEC/LOEC survival	7 d	160 d	7.0	soft	18	?	12	?	Buckler, et al. 1987	N	N
Striped Bass	*Marone saxatilis*	$Al_2(SO_4)_3$	87.2	-	87.2/174.4	total	NOEC/LOEC survival	7 d	160 d	6.5	soft	18	?	12	?	Buckler, et al. 1987	N	N
Striped Bass	***Marone saxatilis***	$Al_2(SO_4)_3$	-	-	**21.8/43.6**	**total**	**NOEC/LOEC survival**	**7 d**	**160 d**	**6.0**	**soft**	**18**	**?**	**12**	**?**	**Buckler, et al. 1987**	**N**	**N**
Brook Trout	*Salvelinus fontinalis*	$Al_2(SO_4)_3$	-	-	88/169	total	NOEC/LOEC growth	60 d	eyed eggs	6.5	246	12?	?	68	low	Cleveland, et al. 1986	NI	N
Brook Trout	***Salvelinus fontinalis***	$Al_2(SO_4)_3$	-	-	**169/350**	**total**	**NOEC/LOEC survival**	**60 d**	**eyed eggs**	**6.5**	**246**	**12?**	**?**	**68**	**low**	**Cleveland, et al. 1986**	**NI**	**N**

Notes:
Data used in EPA 1988 calculation
TLm = tolerance limit
dph = days post hatch
NR = not reported
? = Information not found in original paper
NI = Not enough information in paper
to determine if requirement was met

TABLE 3. ALUMINUM CHRONIC TOXICITY DATABASE

COMMON NAME	GENUS SPECIES	Comments
Cladoceran	*Ceriodaphnia dubia*	raw lake superior water used for dilution water, TOC?, photoperiod not specified
Cladoceran	*Daphnia magna*	well water used for dilution water, TOC?, control failure
Fathead minnow	*Pimephales promelas*	well water used for dilution water, TOC?
Fathead minnow	*Pimephales promelas*	well water used for dilution water, TOC?
Striped Bass	*Marone saxatilis*	test duration not appropriate
Striped Bass	*Marone saxatilis*	test duration not appropriate
Striped Bass	***Marone saxatilis***	**test duration not appropriate**
Brook Trout	*Salvelinus fontinalis*	controls contained 4-5ug/L Al. Source of dilution water noted in different paper(RO+well water)?, test temp. not known
Brook Trout	***Salvelinus fantinalis***	**controls contained 4-5ug/L Al. Source of dilution water noted in diffetent paper(RO+well water)?, test temp. not known**

Notes:
Data used in EPA 1988 calculation
TLm = tolerance limit
dph = days post hatch
NR = not reported
? = information not found in original paper
NI = Not enough information in paper
to determine if requirement was met

TABLE 4. ACUTE AND CHRONIC DATA NOT USED IN ALUMINUM CRITERIA CALCULATION

Common Name	Genus Species	Form Of Aluminum Tested	Toxicity Value: Value Reported ins: EPA 1988 (µg/L)	AQUIRE (µg/L)	PAPER (µg/L)	Total Or Dissolved[1]	Endpoint	Duration	Life Stage	Test Conditions: pH (s.u.)	Hardness (mg/l)	Temp (deg C)	D.O. (mg/L)	Alkalinity (mg/L)	TOC (mg/L)	Reference
ACUTE DATABASE																
Worm	*Caenorhabditis elegans*	$Al(NO_3)_3$	-	2,000	2,000	?	LC50	48 hr	young adult	?	?	20	?	?	?	Williams et al. 1990
Worm	*Caenorhabditis elegans*	$Al(NO_3)_3$	-	1,800	1,800	?	LC50	96 hr	young adult	?	?	20	?	?	?	Williams et al. 1990
Worm	*Tubifex tubifex*	$AlNH_4(SO_4)_2$	-	69,820	69,820	?	EC50	24 hr	?	7.5-7.7	230-250	29-31	5.2-6.0	390-410	?	Khangarot, 1991
Worm	*Tubifex tubifex*	$AlNH_4(SO_4)_2$	-	55,850	55,850	?	EC50	48 hr	?	7.5-7.7	230-250	29-31	5.2-6.0	390-410	?	Khangarot, 1991
Worm	*Tubifex tubifex*	$AlNH_4(SO_4)_2$	-	50,230	50,230	?	EC50	96 hr	?	7.5-7.7	230-250	29-31	5.2-6.0	390-410	?	Khangarot, 1991
Leopard frog	*Rana pipiens*	$AlCl_3$	-	-	471	total monomeric	LC50	96 hr	eggs	4.8	?	20?	?	?	1 (DOC)	Freda et al. 1990 a
frog	*Bufo americanus*	$AlCl_3$	-	-	627	total monomeric	LC50	96 hr	3wk old	4.5	?	20?	?	?	1 (DOC)	Freda et al. 1990 a
Leopard frog	*Rana pipiens*	$AlCl_3$	-	811	811	total monomeric	LC50	4-5 d	eggs	4.6	?	20?	?	?	1 (DOC)	Freda et al. 1990 b
Leopard frog	*Rana pipiens*	$AlCl_3$	-	403	403	total monomeric	LC50	4-5 d	eggs	4.8	?	20?	?	?	1 (DOC)	Freda et al. 1990 b
Rotifer	*Brachionus calyciflorus*	?	-	-	>3000	?	LC50	24 hr	< 2hrs old	7.5?	?	25	?	?	?	Snell et al. 1991
Snail	*Amnicola limosa*	Al wire	-	> 1000	> 1000	total	LC 50	96 hr	?	3.5	15	20-25	?	5.2	?	Mackie, et al 1989
Snail	*Amnicola limosa*	Al wire	-	> 400	> 400	total	LC 50	96 hr	?	4.0	15	20-25	?	5.2	?	Mackie, et al 1989
Snail	*Amnicola limosa*	Al wire	-	400	> 400	total	LC 50	96 hr	?	4.5	15	20-25	?	5.2	?	Mackie, et al 1989
Scud	*Hyalella azteca*	Al wire	-	> 1000	> 1000	total	LC 50	96 hr	?	5.0	15	20-25	?	5.2	?	Mackie, et al 1989
Scud	*Hyalella azteca*	Al wire	-	> 400	> 400	total	LC 50	96 hr	?	5.5	15	20-25	?	5.2	?	Mackie, et al 1989
Scud	*Hyalella azteca*	Al wire	-	> 400	> 400	total	LC 50	96 hr	?	6.0	15	20-25	?	5.2	?	Mackie, et al 1989
Damselfly	*Enallagma sp.*	Al wire	-	> 1000	> 1000	total	LC 50	96 hr	?	3.5	15	20-25	?	5.2	?	Mackie, et al 1989
Damselfly	*Enallagma sp.*	Al wire	-	> 400	> 400	total	LC 50	96 hr	?	4.0	15	20-25	?	5.2	?	Mackie, et al 1989
Damselfly	*Enallagma sp.*	Al wire	-	> 400	> 400	total	LC 50	96 hr	?	4.5	15	20-25	?	5.2	?	Mackie, et al 1989
Amphipod	*Crangonyx pseudogracilis*	$Al_2(SO_4)_3$	-	12,800	12,800	total	LC50	48 hr	adult	6.75	50	13	?	?	?	Martin and Holdich 1986
Amphipod	*Crangonyx pseudogracilis*	$Al_2(SO_4)_3$	-	9,190	9,190	total	LC50	96 hr	adult	6.75	50	13	?	?	?	Martin and Holdich 1986
Isopod	*Asellus aquaticus*	$Al_2(SO_4)_3$	-	6,570	6,570	total	LC50	48 hr	adult	6.75	50	13	?	?	?	Martin and Holdich 1986
Isopod	*Asellus aquaticus*	$Al_2(SO_4)_3$	-	4,370	4,370	total	LC50	72 hr	adult	6.75	50	13	?	?	?	Martin and Holdich 1986
Cladoceran	*Daphnia pulex*	?	-	NR	350	total?	LC50	48 hr	< 24 hr	7.25	10	20	9.13	?	?	Curtis et al. 1992
Cladoceran	*Daphnia pulex*	?	-	NR	420	total?	LC50	48 hr	< 24 hr	7.25	30	20	9.13	?	?	Curtis et al. 1992
Cladoceran	*Daphnia pulex*	?	-	NR	> 1940	total?	LC50	48 hr	< 24 hr	7.25	80	20	9.13	?	?	Curtis et al. 1992
Cladoceran	*Daphnia pulex*	?	-	NR	520	total?	LC50	48 hr	< 24 hr	8.25	10	20	9.13	?	?	Curtis et al. 1992
Cladoceran	*Daphnia pulex*	?	-	NR	380	total?	LC50	48 hr	< 24 hr	8.25	30	20	9.13	?	?	Curtis et al. 1992
Cladoceran	*Daphnia pulex*	?	-	NR	420	total?	LC50	48 hr	< 24 hr	8.25	80	20	9.13	?	?	Curtis et al. 1992
Cladoceran	*Daphnia pulex*	?	-	NR	440	total?	LC50	48 hr	< 24 hr	8.25	120	20	9.13	?	?	Curtis et al. 1992
Cladoceran	*Daphnia magna*	Na2Al	> 40,000	-	> 40,000	total	TLm	96 hr	24 hr +/- 12 hr	?	27	18	?	25	?	Peterson et al 1974
Cladoceran	*Daphnia magna*	$AlCl_3$	3,900	-	3,900	total	LC50	48 hr	< 24 hr	6.5-7.5	45.3	18?	near sat.	42.3	?	Besinger and Christensen 1972
Cladoceran	*Daphnia magna*	$Al_2(SO4)_3$	21,450	-	21,450	?	Threshold conc.	16 hr	< 8 hr	?	?	25	?	97-100	?	Anderson 1944
Cladoceran	*Daphnia magna*	$AlNH_4(SO_4)_2$	21,620	-	21,620	?	Threshold conc.	16 hr	< 8 hr	?	?	25	?	97-100	?	Anderson 1944
Cladoceran	*Daphnia magna*	$AlK(SO_4)_2$	21,530	-	21,530	?	Threshold conc.	16 hr	< 8 hr	?	?	25	?	97-100	?	Anderson 1944
Cladoceran	*Daphnia magna*	$AlNH_4(SO_4)_2$	85,920	-	85,920	?	EC50	24 hr	?	7.2-7.8	235-260	11.5-14.5	5.2-6.5	390-415	?	Khangarot, 1989
Cladoceran	*Daphnia magna*	$AlNH_4(SO_4)_2$	59,600	-	59,600	?	EC50	48 hr	?	7.2-7.8	235-260	11.5-14.5	5.2-6.5	390-415	?	Khangarot, 1989
Cladoceran	*Ceriodaphnia dubia*	$Al_2(SO_4)_3$	-	-	<138 / <23.5	total / diss	LC50	48 hr	< 24 hr	6.5	7.5	20	?	7.5	< 5	ASci Al WER for 3M, 1994
Cladoceran	*Ceriodaphnia dubia*	$Al_2(SO_4)_3$	-	-	156 / 7.945	total / diss	LC50	48 hr	< 24 hr	6.5	7.5	20	?	7.5	< 5	ASci Al WER for 3M, 1994
Cladoceran	*Ceriodaphnia dubia*	$AlCl_3$	-	1,500	1,500	total	EC50	48 hr	< 24 hr	7.86	50.5	25	?	39.6	?	McCauley et al 1986
Cladoceran	*Ceriodaphnia dubia*	$Al_2(SO_4)_3$	-	NR	2,880	?	LC50	48 hr	?	7.9?	?	25?	?	?	?	Soucek et al. 2001
Cladoceran	*Ceriodaphnia dubia*	$Al_2(SO_4)_3$	-	-	149.5 / 26.35	total / diss	LC50	48 hr	< 24 hr	6.5	7.5	20	?	7.5	< 5	ASci Al WER for 3M, 1994
Rainbow Trout	*Oncorhynchus mykiss*	$Al_2(SO_4)_3$	-	-	208.9 / 24.5	total / diss	LC50	96 hr	fry	7.5	40-50	12	?	?	< 5	ASci Al WER for 3M, 1994
Rainbow Trout	*Oncorhynchus mykiss*	$AlCl_3$	8,600	NR	8,600	total	LC50	96 hr	juvenile	7.46	47.4	?	?	41.6	?	Call 1984
Rainbow Trout	*Salmo gairdneri*	$AlCl_3$	-	112	112	?	LT50	27 hr	180-340 g	4.8	?	14	?	?	?	Goss and Wood 1988
Rainbow Trout	*Oncorhynchus mykiss*	$AlCl_3$	-	-	1,240 / 214	total / diss	LC 50	96 hr	juvenile	5.4	40.7	12	10.6	?	?	Besser et al 2003
Rainbow Trout	*Oncorhynchus mykiss*	$AlCl_3$	-	-	225 / 203	total / diss	LC 50	96 hr	juvenile	5.3	117	12	10.6	?	?	Besser et al 2003
Fathead minnow	*Pimephales promelas*	$AlCl_3$	-	NR	60.95	?	LC50	96 hr	28 dph	5.5	21	21.5	8.4	23.2	0.9	Palmer et al 1989
Fathead minnow	*Pimephales promelas*	alum	>18,900	NR	?	?	LC50	96 hr	?	4.14-7.6	?	25	?	14.5-64.4	?	Boyd, 1979
Brook Trout	*Salvelinus fontinalis*	$Al_2(SO_4)_3$	-	4,000	4,000	total	LD 50	96 hr	juvenile	5.5	?	11	?	?	?	Decker and Menendez 1974
Brook Trout	*Salvelinus fontinalis*	$AlCl_3$	-	-	1,370 / 285	total / diss	LC 50	96 hr	juvenile	5.4	40.7	12	10.8	?	?	Besser et al 2003
Brook Trout	*Salvelinus fontinalis*	$AlCl_3$	-	-	298 / 228	total / diss	LC 50	96 hr	juvenile	5.3	117	12	10.6	?	?	Besser et al 2003
Brook Trout	*Salvelinus fontinalis*	$AlCl_3$	-	-	213 / 160	total / diss	LC 50	96 hr	juvenile	5.3	111	12	11.1	?	?	Besser et al 2003
Brook Trout	*Salvelinus fontinalis*	$AlCl_3$	-	-	1,280 / 208	total / diss	LC 50	96 hr	juvenile	5.3	?	12	9.6	?	?	Besser et al 2003
Mosquitofish	*Gambusia affinis*	$AlCl_3$	26,900	27,100	26,910	?	TLm	96 hr	adult	4.3-7.2	?	20-21	?	?	?	Wallen et al. 1957
Mosquitofish	*Gambusia affinis*	$AlCl_3$	-	27,500	27,316	?	TLm	48 hr	adult	4.3-7.2	?	20-21	?	?	?	Wallen et al. 1957
Mosquitofish	*Gambusia affinis*	$Al_2(SO_4)_3$	-	-	37,060	?	TLm	96 hr	adult	4.4-7.7	?	19-22	?	?	?	Wallen et al. 1957
Mosquitofish	*Gambusia affinis*	$Al_2(SO_4)_3$	-	-	37,852	?	TLm	48 hr	adult	4.4-7.7	?	19-22	?	?	?	Wallen et al. 1957
Grass carp	*Ctenopharyngodon idellus*	?	-	260	260	dissolved	LC50	96 hr	fry	5.0	?	?	?	?	?	Li et al. 1982
Atlantic Salmon	*Salmo salar*	$AlCl_3$	-	584	584	total	LC50	96 hr	alevins	5.5	6.6	12	?	1.6	?	Hamilton et al. 1995
Atlantic Salmon	*Salmo salar*	$AlCl_3$	-	599	599	total	LC50	96 hr	alevins	6.5	6.6	12	?	1.6	?	Hamilton et al. 1995

TABLE 4. ACUTE AND CHRONIC DATA NOT USED IN ALUMINUM CRITERIA CALCULATION

Common Name	Genus Species	Form Of Aluminum Tested	Toxicity Value: Value Reported Ins: EPA 1988 (µg/L)	AQUIRE (µg/L)	PAPER (µg/L)	Total Or Dissolved[1]	Endpoint	Duration	Life Stage	Test Conditions: pH (s.u.)	Hardness (mg/l)	Temp (deg C)	D.O. (mg/L)	Alkalinity (mg/L)	TOC (mg/L)	Reference
CHRONIC DATABASE																
Cladoceran	*Ceriodaphnia sp.*	$AlCl_3$	-	-	8,600	total	LC50	7 d	< 16 hr	7.58	47.4	20-22	6.92	41.6	?	Call 1984
Cladoceran	*Daphnia dubia*	$AlCl_3$	-	1,600	1,600	total	MATC	7 d	< 16 hr	7.61	50.5	25	7.1	39.6	?	McCauley et al 1986
Cladoceran	*Daphnia magna*	$Al_2(SO_4)_3$	-	-	1890 / 4260	?	NOEC/LOEC repro.	28 d	< 24 hr	8.3	220	19.9	7.81	211	?	Kimball manuscript
Midge	*Tanytarsus dissimilis*	$Al_2(SO_4)_3$	632	-	?	total	?	55 d	2nd instar	6.63	17.43	20	?	?	?	Lamb and Bailey 1981
Cladoceran	*Daphnia magna*	$AlCl_3$	320	-	320	total	EC16	3 wks	< 24 hr	6.5-7.5	45.3	18	near sat.	42.3	?	Besinger and Christensen 1972
Cladoceran	*Daphnia magna*	$AlCl_3$	1,400	-	1,400	total	LC50	3 wks	< 24 hr	6.5-7.5	45.3	18	near sat.	42.3	?	Besinger and Christensen 1972
Brook Trout	*Salvelinus fontinalis*	$Al_2(SO_4)_3$	-	-	142 / 292	total	NOEC/LOEC survival	60 d	eyed eggs	5.5	255	12?	?	10	low	Cleveland, et al. 1986
Brook Trout	*Salvelinus fontinalis*	$Al_2(SO_4)_3$	-	-	>300	?	LC50	30 d	eyed eggs	4.5, 5.5, 7.2	256-268	12	?	236-244	?	Cleveland, et al. 1986
Brook Trout	*Salvelinus fontinalis*	$Al_2(SO_4)_3$	-	-	?	total	NOEC/LOEC growth	60 d	eyed eggs	5.5	255	12?	?	10	low	Cleveland, et al. 1986
Brook Trout	*Salvelinus fontinalis*	$Al_2(SO_4)_3$	283	-	283	total	-	60 d	eyed eggs	7.8	<9	12	?	759	?	Hunn et al. 1987
Atlantic Salmon	*Salmo salar*	$Al_2(NO_3)_3$	-	-	402	total	LT50	85 hr	?	5.2	?	9.2	?	?	?	Poleo, et al. 1997
Atlantic Salmon	*Salmo salar*	$Al_2(SO_4)_3$	-	-	71 / 124	nominal total?	NOEC/LOEC survival	60 dph	eggs	5.5	254 ueq/l	8	?	240 ueq/l	?	Buckler et al. 1995
Atlantic Salmon	*Salmo salar*	$Al_2(SO_4)_3$	-	-	[illegible]	nominal total?	NOEC/LOEC growth	60 dph	eggs	5.5	254 ueq/l	8	?	240 ueq/l	?	Buckler et al. 1995
Atlantic Salmon	*Salmo salar*	$Al_2(SO_4)_3$	-	78	78	Inorganic mono Al	LC50	96 hr	juvenile	5.0	?	10?	>85%	?	<5	Roy and Campbell 1997
Rainbow Trout	*Oncorhynchus mykiss*	$AlCl_3$	-	NR	1940 / 430	total / diss	LC50	16 d	juvenile	8.0	20.3	14?	?	?	?	Gundersen et al. 1994
Rainbow Trout	*Oncorhynchus mykiss*	$AlCl_3$	-	NR	3910 / 670	total / diss	LC50	16 d	juvenile	8.0	103	14?	?	?	?	Gundersen et al. 1994
Rainbow Trout	*Oncorhynchus mykiss*	$AlCl_3$	5,200	-	5,200	total	TL50	3 d	6 mths old	8.99	?	13	?	?	?	Freeman and Everhart 1971
Rainbow Trout	*Oncorhynchus mykiss*	$AlCl_3$	5,140	-	5,140	total	TL50	7.5 d	6 mths old	8.48	?	13	?	?	?	Freeman and Everhart 1971
Rainbow Trout	*Oncorhynchus mykiss*	$AlCl_3$	5,230	-	5,230	total	TL50	32 d	6 mths old	8.02	?	13	?	?	?	Freeman and Everhart 1971
Rainbow Trout	*Oncorhynchus mykiss*	$AlCl_3$	5,140	-	5,140	total	TL50	39 d	6 mths old	6.8	?	13	?	?	?	Freeman and Everhart 1971
Rainbow Trout	*Oncorhynchus mykiss*	$AlCl_3$	513	-	513	total	TL50	44 d	6 mths old	6.64	?	13	?	?	?	Freeman and Everhart 1971
Rainbow Trout	*Salmo gairdneri*	$Al_2(SO_4)_3$	75	-	75	?	none	11 d	juvenile	6.5	?	10	?	?	?	Neville, et al. 1985
Rainbow Trout	*Salmo gairdneri*	$AlCl_3$	560	-	560	?	LC50	28 d	eggs	7.4	104	13	9.3-10.1	?	?	Birge, et al. 1979
Goldfish	*Carassius auratus*	$AlCl_3$	150	-	150	?	LC50	7 d	eggs	7.4	195	22	9.3-10.1	?	?	Birge, et al. 1979, 1978
Narrow-mouthed toad	*Gastrophryne carolinensis*	$AlCl_3$	50	-	50	?	LC50	7 d	eggs	7.4	195	22	9.3-10.1	?	?	Birge, et al. 1979, 1978
Large-mouthed bass	*Micropterus salmoides*	$AlCl_3$	170	-	170	?	LC50	8 d	eggs	7.2-7.8	93-105	19-22	near sat.	?	?	Birge, et al. 1978
Marbled salamander	*Ambystoma opacum*	$AlCl_3$	2,280	-	2,280	?	LC50	8 d	eggs	7.2-7.8	93-105	19-22	near sat.	?	?	Birge, et al. 1978
Three spined stickleback	*Gasterosteus aculeatus*	$Al(NO_3)_3$	70	-	70	?	lethal limit	10 d	?	?	?	15-18	?	?	?	Jones 1939
Green algae	*Chlorella vulgaris*	$AlCl_3$	4,000	-	4,000	?	inhibited growth	3-4 mths	-	>7.0	?	rm temp	?	?	?	De Jong 1965
Aquatic beetle	*Tropisternus lateralis nimbatus*	$AlCl_3$	200	27,000	27,000	?	changes in body fat	14 d	adult	7.0	?	?	?	?	?	Wooldridge 1969
algae	*Selenastrum capricornutum*	$Al_2(SO_4)_3$	-	-	630	total	IC50	72 hr	-	6.3	10	24	?	?	?	Condon, et al 2004
algae	*Selenastrum capricornutum*	$Al_2(SO_4)_3$	-	-	170	total	IC50	72 hr	-	6.3-7.0	50	24	?	?	?	Condon, et al 2004
algae	*Selenastrum capricornutum*	$Al_2(SO_4)_3$	-	-	220	total	IC50	72 hr	-	7.0	90	24	?	?	?	Condon, et al 2004
algae	*Selenastrum capricornutum*	$AlCl_3$	570	-	570	total	EC50	4 d	-	7.6	14.9	25	?	?	?	Call 1984
algae	*Selenastrum capricornutum*	$AlCl_3$	460	-	460	total	EC50	4 d	-	8.2	14.9	25	?	?	?	Call 1984
Watermilfoil	*Myriophyllum spicatum*	?	2,500	-	2,500	?	EC50 root weight	32 d	?	?	?	?	?	?	?	Stanley 1974
Diatom	*Cyclotella meneghiniana*	$AlCl_3$	810	-	800	?	inhibited growth	8 d	-	7.9	?	26	?	?	?	Rao et al. 1982
Green algae	*Chlorella vulgaris*	$AlCl_3$	-	-	107,920	total	LC50	15 d	-	6.8	?	26	?	?	?	Rai, et al. 1998
Green algae	*Chlorella vulgaris*	$AlCl_3$	-	-	5,935	total	LC50	15 d	-	6.0	?	26	?	?	?	Rai, et al. 1998
Green algae	*Chlorella vulgaris*	$AlCl_3$	-	-	4,047	total	LC50	3 d	-	4.5	?	26	?	?	?	Rai, et al. 1998

Notes:
TLm = tolerance limit
dph = days post hatch
NR = not reported
? = information not found in original paper
1. Samples filtered through 0.4 or 0.45 um filter

TABLE 4. ACUTE AND CHRONIC DATA NOT USED IN ALUMINUM CRITERIA CALCULATION

Common Name	Genus Species	COMMENTS
ACUTE DATABASE		
Worm	*Caenorhabditis elegans*	dilution water = "Kmedium", conc. Measured?, young adults used
Worm	*Caenorhabditis elegans*	dilution water = "Kmedium", conc. Measured?, young adults used
Worm	*Tubifex tubifex*	organism age, control performance, feeding not known, Al salt may not be appropriate due to NH4
Worm	*Tubifex tubifex*	organism age, control performance, feeding not known, Al salt may not be appropriate due to NH4
Worm	*Tubifex tubifex*	organism age, control performance, feeding not known, Al salt may not be appropriate due to NH4
Leopard frog	*Rana pipiens*	test temp, photoperiod, grade of test material not given, dilution water made from dechlor tap + DI to equal soft water
frog	*Bufo americanus*	test temp, photoperiod, grade of test material not given, dilution water made from dechlor tap + DI to equal soft water
Leopard frog	*Rana pipiens*	test temp, photoperiod, grade of test material not given, dilution water made from dechlor tap + DI to equal soft water
Leopard frog	*Rana pipiens*	test temp, photoperiod, grade of test material not given, dilution water made from dechlor tap + DI to equal soft water
Rotifer	*Brachionus calyciflorus*	test duration may not be acceptable, Al salt and grade of material not given
Snail	*Amnicola limosa*	Age of organism, control performance info not given, test material not appropiate
Snail	*Amnicola limosa*	Age of organism, control performance info not given, test material not appropiate
Snail	*Amnicola limosa*	Age of organism, control performance info not given, test material not appropiate
Scud	*Hyalella azteca*	Age of organism, control performance info not given, test material not appropiate
Scud	*Hyalella azteca*	Age of organism, control performance info not given, test material not appropiate
Scud	*Hyalella azteca*	Age of organism, control performance info not given, test material not appropiate
Damselfly	*Enallagma sp.*	Age of organism, control performance info not given, test material not appropiate
Damselfly	*Enallagma sp.*	Age of organism, control performance info not given, test material not appropiate
Damselfly	*Enallagma sp.*	Age of organism, control performance info not given, test material not appropiate
Amphipod	*Crangonyx pseudogracilis*	control performance not known,1:3 ratio tap to deionized water used for dilution water, used nominal concentrations
Amphipod	*Crangonyx pseudogracilis*	control performance not known,1:3 ratio tap to deionized water used for dilution water, used nominal concentrations
Isopod	*Asellus aquaticus*	Not resident N. American species (as per 1985 Guidance) control performance not known,1:3 ratio tap to deionized water used for dilution water, used nominal concentrations
Isopod	*Asellus aquaticus*	Not resident N. American species (as per 1985 Guidance) control performance not known,1:3 ratio tap to deionized water used for dilution water, used nominal concentrations
Cladoceran	*Daphnia pulex*	Al salt and grade, feeding unknown
Cladoceran	*Daphnia pulex*	Al salt and grade, feeding unknown
Cladoceran	*Daphnia pulex*	Al salt and grade, feeding unknown
Cladoceran	*Daphnia pulex*	Al salt and grade, feeding unknown
Cladoceran	*Daphnia pulex*	Al salt and grade, feeding unknown
Cladoceran	*Daphnia pulex*	Al salt and grade, feeding unknown
Cladoceran	*Daphnia pulex*	Al salt and grade, feeding unknown
Cladoceran	*Daphnia magna*	control performance, source of organisms, feeding not known, test temp not appropriate
Cladoceran	*Daphnia magna*	used lake water for dilution water, control performance not known, concentrations not measured
Cladoceran	*Daphnia magna*	Lake Erie water used as dilution water, culture water made with manure-soil mix therefore, not known if test organisms were exposed to other toxicants, test pH not known
Cladoceran	*Daphnia magna*	Lake Erie water used as dilution water, culture water made with manure-soil mix therefore, not known if test organisms were exposed to other toxicants, test pH not known
Cladoceran	*Daphnia magna*	Lake Erie water used as dilution water, culture water made with manure-soil mix therefore, not known if test organisms were exposed to other toxicants, test pH not known
Cladoceran	*Daphnia magna*	age, control performance unknown, used feral organisms, "tubewell" water used for dilution water, Al salt may not be appropriate due to NH4
Cladoceran	*Daphnia magna*	age, control performance unknown, used feral organisms, "tubewell" water used for dilution water, Al salt may not be appropriate due to NH5
Cladoceran	*Ceriodaphnia dubia*	all organisms died except controls therefore, not appropriate LC50
Cladoceran	*Ceriodaphnia dubia*	CONTROL FAILURE
Cladoceran	*Ceriodaphnia dubia*	Confid. Intervals not reliable, dechlorinated tap water used for dilution water, photoperiod not specified
Cladoceran	*Ceriodaphnia dubia*	control performance, feeding during test, age of test organisms not given, not sure of test temp, pH
Cladoceran	*Ceriodaphnia dubia*	test value more than an factor of 10 difference from other studies
Rainbow Trout	*Oncorhynchus mykiss*	tox value more than 10X difference than other tests with same species
Rainbow Trout	*Oncorhynchus mykiss*	Al "aged" dilution water for 18 days, unprocessed lake water used for dilution water
Rainbow Trout	*Salmo gairdneri*	24 hr light photoperiod?, test duration, endpoint not appropriate, fish starved 2 weeks before test
Rainbow Trout	*Oncorhynchus mykiss*	Ca = 13 mg/L, TOC not tested, but well water typically doesn't have DOC
Rainbow Trout	*Oncorhynchus mykiss*	Ca = 40 mg/L, TOC not tested, but well water typically doesn't have DOC
Fathead minnow	*Pimephales promelas*	Advent calc LC50 from figure data, dilution water made from mix of DI and well water
Fathead minnow	*Pimephales promelas*	controls, feeding, chemical grade, organism age not known. No LC50 given
Brook Trout	*Salvelinus fantinalis*	AQUIRE had these listed under Iron salt, carbon filtered tap water used for dilution water
Brook Trout	*Salvelinus fantinalis*	Ca = 13 mg/L, TOC not tested, but well water typically doesn't have DOC
Brook Trout	*Salvelinus fantinalis*	Ca = 40 mg/L, TOC not tested, but well water typically doesn't have DOC
Brook Trout	*Salvelinus fantinalis*	Ca = 40 mg/L, TOC not tested, but well water typically doesn't have DOC
Brook Trout	*Salvelinus fantinalis*	Ca = 40 mg/L, TOC not tested, but well water typically doesn't have DOC
Mosquitofish	*Gambusia affinis*	dilution water has high turbidity, control performance not known, test pH range high variability
Mosquitofish	*Gambusia affinis*	dilution water has high turbidity, control performance not known, test pH range high variability
Mosquitofish	*Gambusia affinis*	dilution water has high turbidity, control performance not known, test pH range high variability
Mosquitofish	*Gambusia affinis*	dilution water has high turbidity, control performance not known, test pH range high variability
Grass carp	*Ctenopharyngodon idellus*	paper in Chinese so can't determine testing details
Atlantic Salmon	*Salmo salar*	control, grade of material not given, measured concentrations?
Atlantic Salmon	*Salmo salar*	control, grade of material not given, measured concentrations?

TABLE 4. ACUTE AND CHRONIC DATA NOT USED IN ALUMINUM CRITERIA CALCULATION

Common Name	Genus Species	COMMENTS
CHRONIC DATABASE		
Cladoceran	*Ceriodaphnia sp.*	control failure, unprocessed lake water used for dilution water
Cladoceran	*Daphnia dubia*	dechlorinated tap water used for dilution water, photoperiod not specified
Cladoceran	*Daphnia magna*	well water used for dilution water, control failure
Midge	*Tanytarsus dissimilis*	dilution water was filtered lake water, no info on feeding, control performance
Cladoceran	*Daphnia magna*	used lake water for dilution water, control performance not known, concentrations not measured
Cladoceran	*Daphnia magna*	used lake water for dilution water, control performance not known, concentrations not measured
Brook Trout	*Salvelinus fontinalis*	controls tested at different pH than rest of tests and contained 4-5ug/L Al. Source of dilution water unknown, test temp. not known
Brook Trout	*Salvelinus fontinalis*	tested one concentration at three pHs, no endpoint can be calculated
Brook Trout	*Salvelinus fontinalis*	controls tested at different pH than rest of tests and contained 4-5ug/L Al. Source of dilution water unknown, test temp. not known
Brook Trout	*Salvelinus fontinalis*	control 80% mort., dilution water very soft, no endpt. calculated; no mortality effect, but growth effect
Atlantic Salmon	*Salmo salar*	Many other fish species tested here, but endpoints, duration not appropriate, fish age, control performance not given for all.
Atlantic Salmon	*Salmo salar*	test temp too low?
Atlantic Salmon	*Salmo salar*	test temp too low? Growth significance compared to control in different pH
Atlantic Salmon	*Salmo salar*	pH too low, control performance, feeding, test temp, not given.
Rainbow Trout	*Oncorhynchus mykiss*	test temp, grade of test material not given
Rainbow Trout	*Oncorhynchus mykiss*	test temp, grade of test material not given
Rainbow Trout	*Oncorhynchus mykiss*	test durations not standard (paper called it chronic), in EPA Table 6
Rainbow Trout	*Oncorhynchus mykiss*	test durations not standard, in EPA Table 6
Rainbow Trout	*Oncorhynchus mykiss*	test durations not standard, in EPA Table 6
Rainbow Trout	*Oncorhynchus mykiss*	test durations not standard, in EPA Table 6
Rainbow Trout	*Oncorhynchus mykiss*	test durations not standard, in EPA Table 6
Rainbow Trout	*Salmo gairdneri*	test duration not standard, test was to determine concentration of respiratory effects
Rainbow Trout	*Salmo gairdneri*	controls, dilution water, source of test organisms, photoperiod, feeding info not given, test duration not appropriate (4d post hatch)
Goldfish	*Carassius auratus*	controls, dilution water, source of test organisms, photoperiod, feeding info not given, test duration not appropriate (4d post hatch)
Narrow-mouthed toad	*Gastrophryne carolinensis*	controls, dilution water, source of test organisms, photoperiod, feeding info not given, test duration not appropriate (4d post hatch)
Large-mouthed bass	*Micropterus salmoides*	controls, dilution water, source of test organisms, feeding info not given, test duration not appropriate (4d post hatch)
Marbled salamander	*Ambystoma opacum*	controls, dilution water, source of test organisms, feeding info not given, test duration not appropriate (4d post hatch)
Three spined stickleback	*Gasterosteus aculeatus*	tap water used for dilution water, no info on control, chemical grade, organism age
Green algae	*Chlorella vulgaris*	controls, photoperiod,test temp not given, test duration not appropriate
Aquatic beetle	*Tropisternus lateralis nimbatus*	deionized water without salts used for dilution water, organism age not acceptable, control performance, test temp, photoperiod not given
algae	*Selenastrum capricornutum*	TOC? Test duration should be 96 hr
algae	*Selenastrum capricornutum*	TOC? Test duration should be 96 hr
algae	*Selenastrum capricornutum*	TOC? Test duration should be 96 hr
algae	*Selenastrum capricornutum*	growth medium used for dilution water (contained EDTA??)
algae	*Selenastrum capricornutum*	growth medium used for dilution water (contained EDTA??)
Watermilfoil	*Myriophyllum spicatum*	not enough test info given
Diatom	*Cyclotella meneghiniana*	not enough test info given, paper gives endpoint as "almost inhibited growth"
Green algae	*Chlorella vulgaris*	test duration must be 96hr. grade of test material? TOC? control performance acceptable? Test conc.measured?
Green algae	*Chlorella vulgaris*	test duration must be 96hr. grade of test material? TOC? control performance acceptable? Test conc.measured?
Green algae	*Chlorella vulgaris*	test duration must be 96hr. grade of test material? TOC? control performance acceptable? Test conc.measured?

Notes:
TLm = tolerance limit
dph = days post hatch
NR = not reported
? = information not found in original paper
1. Samples filtered through 0.4 or 0.45 um filter

ATTACHMENT 1

Bibliography

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ATTACHMENT 1

ALUMINUM TOXICITY BIBLIOGRAPHY

Abdelhamid, A.M.; S.A. El Ayouty. 1991. Effect on Catfish (*Clarias lazera*) Composition of Ingestion Rearing Water Contaminated with Lead or Aluminum Compounds *Arch Anim Nutr, Berlin*, 41(7/8): 757-763.

Alexopoulos, E.; et al. 2003. Bioavailability and Toxicity of Freshly Neutralized Aluminum to the Freshwater Crayfish (*Pacifastacus lenisusculus*). *Arch. Environ. Contam. Tox.*, 45: 509-514.

Allen, Herbert E.; et al. ?. The Importance of Trace Metal Speciation to Water Quality Criteria. *Water Environment Research*, 68(1): 42-54.

Allin, C.J.; et al. 2000. Effects of Pre-Acclimation to Aluminum on the Physiology and Swimming Behavior of Juvenile Rainbow Trout (*Oncorhynchus mykiss*) During a Pulsed Exposure. *Aquat. Tox.*, 51: 213-224.

Anderson, B.G. 1944. The Toxicity Thresholds of Various Substances Found in Industrial Wastes as Determined by the Use of *Daphnia magna*. *Sewage Works*: 16: 1156-1165.

AScI Corporation/AScI Duluth. 1994. Aluminum Water-Effect Ratio for the 3M Middleway Plant Effluent Discharge Middleway, West Virginia.

Atland, A. 1998. Behavioural Responses of Brown Trout, *Salmo trutta*, Juveniles in Concentration Gradients of pH and Al - A Laboratory Study. *Environ. Bio. Fish.*, 53: 331-345.

Baker, J.P. and C.L. Schofield. 1982. Aluminum Toxicity to Fish in Acidic Waters. *Water, Air, Soil Poll.*, 18: 289-309.

Baker, Lawrence A.; et al. 1990. Current Status of Surface Water Acid-Base Chemistry. *NAPAP State of Science and Technology*, II:13/52-15/135.

Baker, J.P., J. Van Sickle, C.J. Gagen, D.R. DeWalle, W.E. Sharpe, R.F. Carline, B.P. Baldigo, P.S. Murdoch, D.W. Bath, W.A. Kretser, H.A. Simonin, and P.J. Wigington Jr. 1996. Episodic Acidification of Small Streams in the Northeastern United States: Effects on Fish Populations. *Ecological Applications* 6(2): 422-437.

Beattie, R.C., R. Tyler-Jones, M.J. Baxter. 1992. The Effects of pH, Aluminium Concentration and Temperature on the Embryonic Development of the European Common Frog, *Rana temporaria*. *J. Zool.*, 228: 557-570.

Becker, A.J., Jr. and E.C. Keller. Jr. 1973. The Effects of Iron and Sulfate on the Growth of *Chlorella*. *Proc. W. Va. Acad. Sci.* 45: l27-135.

Besser, J.M.; et al. 2000. Bioavailability of Metals in Stream Food Webs and Hazards to Brook Trout (*Salvelinus fontinalis*) in the Upper Animas River Watershed, Colorado. *Arch. Environ. Contam. Tox.*, 40: 48-59.

Besser, J.M., W.G. Brumbaugh, C.D. Ivey, D.R. Buckler, and C.G. Ingersoll. 2003. Effects of Calcium and Equilibration Time on the Toxicity of Aluminum to Brook Trout and Rainbow Trout. In Preceedings of Society of Environmental Toxicology and Chemistry 24thAnnual Meeting Austin, TX 2003.

Bi, S.P., S.Q. An, M. Yang, and T. Chen. 2001. Dynamics of Aluminum Speciation in Forest-well Drainage Waters from the Rhode River Watershed, Maryland. *Environ Int.* May 26 (5-6): 377-380.

Biesinger, *K.l.* and CM. Christensen. 1972. Effects of Various Metals on Survival, Growth, Reproduction, and Metabolism of *Daphnia magna. J. Fish. Res. Board Can.* 29: 1691-1700.

Birge, W.J. 1978. Aquatic Toxicology of Trace Elements in Coal and Fly Ash. In: *Energy and Environmental Stress in Aquatic Systems.* Thorp, J.H. and J.W. Gibbons (Eds.). CONT-771114 National Technical Information Service. Springfield. VA. pp 219-240.

Birge, W.J., J.E. Hudson, J.A. Black and A.G. Westerman. 1978. Embryo-Larval Bioassays on Inorganic Coal Elements and *In Situ* Biomonitoring of Coal-Waste Effluents. In: *Surface mining and fish/wildlife needs in the eastern United States.* Samuel. D.E., J.R. Stauffer. C.H. Hocutt and M.T. Mason (Eds.). PB-298353 or FWS/OBS-78/81. National Technical Information Service. Springfield, VA. pp. 97-104.

Birge. W.J., J.A. Black and A.G. Westerman. 1979. Evaluation of Aquatic Pollutants Using Fish and Amphibian Eggs as Bioassay Organisms. In: *Animals as Monitors of Environmental Pollutants.* Nielson, S.W., G. Migaki and D.G. Scarrelli (Eds.). National Academy of Sciences, Washington, DC. pp. 108-118.

Birge. W.J.. J.A. Black, A.G. Westerman and J.E. Hudson. 1980. Aquatic Toxicity Tests on Inorganic Elements Occurring in Oil Shale. In: *Oil shale symposium: Sampling, analysis and quality assurance.* Gale, C. (Ed.). PB80-221435 or EPA-600/9-80-022. National Technical Information Service. Springfield. VA. pp. 519-534.

Birge. W.J., J.A. Black: and B.A. Ramey. 1981. The Reproductive Toxicology of Aquatic Contaminants. In: *Hazard assessment of chemicals: Current developments. Vol. 1.* Saxena, J. and F. Fisher (Eds.). Academic Press. New York, NY. pp. 59-115.

Birge, W.J.; R.D. Hoyt; J.A. Black; M.D. Kercher; W.A. Robinson. 1993. Effects of Chemical Stresses on Behavior of Larval and Juvenile Fishes and Amphibians. *American Fisheries Society. Symposium,* 14: 55-65.

Booth, C.E., D.G. McDonald, B.P. Simons, and C.M. Wood. 1988. Effects of Aluminum and Low pH on Net Ion Fluxes and Ion Balance in the Brook Trout (*Salvelinus fontinalis*). *Can. J. Fish. Aquat. Sci.,* 45: 1563-1574.

Boyd, C.E. 1979. Aluminum Sulfate (Alum) for Precipitating Clay Turbidity From Fish Ponds. *Trans. Am. Fish. Soc.* 108: 307-313.

Bradford, D.F., C. Swanson, and M.S. Gordon. 1992. Effects of Low pH and Aluminum on Two Declining Species of Amphibians in the Sierra Nevada, California. *J. Herpet.* 26(4): 369-377.

Brady, L.D. and R.A. Griffiths. 1995. Effects of pH and Aluminium on the Growth and Feeding Behaviour of Smooth and Palmate Newt Larvae. *Ecotoxicology,* 4(5): 299-306.

Bringmann. G. and R. Kuhn. 1953b. Water Toxicology Studies With Protozoans as Test Organisms. *Gesundh.-Ing.* 80: 239-242.

Bringmann. G. and R. Kuhn. 1959a. The Toxic Effects of Waste Water on Aquatic Bacteria, Algae, and Small Crustaceans. *Gesundh.-Ing.* 80: 115-120.

Brodeur, J.C., T. Ytrestoyl, B. Finstad, R.S. MCKinley. 1999. Increase of Heart Rate Without Elevation of Cardiac Output in Adult Atlantic Salmon (*Salmo salar*) Exposed to Acidic Water and Aluminium. *Can. J. Fish. Aquat. Sci,* 56(2): 184-190.

Brodeur, J.C., F. Okland, B. Finstad, D.G. Dixon, and R.S. McKinley. 2001. Effects of Subchronic Exposure to Aluminum in Acidic Water on Bioenergetics of Atlantic Salmon (*Salmo salar*). *Ecotox. Environ. Safety*, 49: 226-234.

Brooke, L. 1985. University of Wisconsin-Superior. Superior. WJ. (Memorandum to C. Stephan. U.S. EPA. Duluth, MN. July 25.)

Brown, D.J. 1983. Effect of Calcium and Aluminum Concentrations on the Survival of Brown Trout (*Salmo trutta*) at Low pH. *Bull. Environ. Contam. Toxicol.* 30: 582-587.

Browne, B.A.; et al. 1993. pH-Dependent Binding of Aluminum by a Fulvic Acid. *Environ. Sci. Technol.*, 224:915-922.

Buccafusco, R.J., S.J. Ells, and G.A. LeBlanc. 1981. Acute Toxicology of Priority Pollutants to Bluegill (*Lepomis macrochirus*). *Bull Environ Contam Toxicol.* Apr 26(4): 446-52.

Buckler, D., P.M. Mehrle, R. L. Cleveland, and F.J. Dwer. 1987. Influence of pH on the Toxicity of Aluminum and Other Organic Contaminants to East Coast Striped Bass. *Water, Air, Soil Poll.*, 35: 97-106.

Buckler, D.R., L. Cleveland, E.E. Little, and W.G. Brumbaugh. 1995. Survival, Sublethal Responses, and Tissue Residues of Atlantic Salmon Exposed to Acidic pH and Aluminum. *Aquat.Toxicol.* 31(3): 203-216.

Buhl, K.J., 2002. The Relative Toxicity of Waterborne Inorganic Contaminants to the Rio Grande Silvery Minnow (*Hybognathus amarus*) and Fathead Minnow (*Pimephales promelas*) in a Water Quality Simulating that in the Rio Grande, New Mexico: Final Report to the US Fish & Wildlife Service, New Mexico Ecological Services Field Office, Albuquerque, NM.

Burrows, W.D. 1977. Aquatic Aluminum: Chemistry, Toxicology, and Environmental Prevalence. *CRC Crit. Rev. Environ. Control* 7: 167-216.

Burton, T. M. and J. W. Allan. 1986. Influence of pH, aluminum, and organic matter on stream invertebrates. *Can. J. Fish. Aquat. Sci.* 43: 1285-1289.

Butcher, G.A. 1988. Water Quality Criteria for Aluminum Technical Appendix. Ministry of Environment and Parks Province of British Columbia. Water Quality Unit.

Call, D.J., L.T. Brooke, C.A. Lindberg, T.P. Markee, D.J. McCauley and S.H. Poirier. 1984. Toxicity of Aluminum to Freshwater Organisms in Water of pH 6.5 to 8.5. Univ. of Wisconsin-Superior, Centre for Lake Superior Environmental Studies, Tech. Report (549-238-RT-WRD).

Campbell, M.M.; K.N. White; R. Jugdaohsingh; J. Powell; C.R. McCrohan. 2000. Effect of Aluminum and Silicic Acid on the Behaviour of the Freshwater Snail *Lymnaea stagnalis Can. J. Fish. Aquat. Sci.*, 57(6): 1151-1159.

Clark, Karen L.; et al. 1983. Effects of Elevated Hydrogen Ion and Aluminum Concentrations on the Survival of Amphibian Embryos and Larvae. *Can. J. Zool.*, 63: 116-123.

Clark, K.L. and B.C. Lazerte. 1985. A laboratory study of the effects of aluminum and pH on amphibian eggs and tadpoles. *Can. J. Fish. Aquat. Sci.* 42:1544-1551.

Cleveland, L., E.E. Little, S.J. Hamilton, D.R. Buckler and J.B. Hunn. 1986. Interactive Toxicity of Aluminum and Acidity to Early Life Stages of Brook Trout. *Trans. Am. Fish. Soc.* 115: 610-620.

Cleveland, L., E.E. Little, R.H. Wiedmeyer, D.R. Buckler. 1989. Chronic No-Observed –Effect Concentrations of Aluminum for Brook Trout Exposed in Low-Calcium, Dilute Acidic Water. In:

Lewis, T.E. ed. Environmental Chemistry and Toxicology of Aluminum. Lewis Publishers, Inc. Chelsea, MI. 344pp.

Cleveland, L., D.R. Buckler, W.G. Brumbaugh. 1991. Residue Dynamics and Effects of Aluminum on Growth and Mortality in Brook Trout *Environ. Tox. Chem.*, 10(2): 243-248.

Condon, C.D. and J.R. Elphick. 2004. Effects of Hardness on the Toxicity of Zinc, Cadmium and Aluminum to *Selenastrum capricormutum.* Poster presentation at Society of Environmental Toxicology and Chemistry 25th Annual Meeting Portland, OR.

Connor, Jody. 1995. Phosphorus Inactivation and Wetland Manipulation Improve Kezar Lake, NH. *USEPA*, 1: 1-7.

Cronan, C.S. and C.L. Schofield. 1979. Aluminum Leaching Response to Acid Precipitation: Effects on High Elevation Watersheds in the Northeast. *Science.* 204: 304-306.

Curtis, Lawrence R.; et al. 1992. Calcium and Organic Acids as Determinants of Aluminum Toxicity at Alkaline and Neutral pH. Final Report *Oak Creek Laboratory of Biology.*

Damkaer, D.M. and D.B. Dey. 1989. Evidence for Fluoride Effects on Salmon Passage at John Day Dam, Columbia River, 1982-1986. *N. Am. J. of Fish. Mgmt.* 9: 154-162.

Decker, C. and R. Menendez. 1974. Acute Toxicity of Iron and Aluminum to Brook Trout. *Proc. W. Virg. Acad. Sci.* 46: 159-167.

De Jong, L.E.D.D. 1965. Tolerance of *Chlorella vulgaris* for Metallic and Non-Metallic Ions. Antonie Leeuwenhoek. *J. Microbiol.* 31: 301-313.

Delonay, A.J., E.E. Little, D.F. Woodword, W.G. Brumbaugh, A.M. Fargag, C.F. Rabeni. 1993. Sensitivity of Early-Life-Stage Golden Trout to Low pH and Elevated Aluminum. *Environ. Toxic. Chem.*, 12: 1223-1232.

DeWalle, D.R., B.R. Swistock, W.E. Sharpe. 1995. Episodic Flow-Duration Analysis: A Method of Assessing Toxic Exposure of Brook trout (*Salvelinus fontinalis*) to Episodic Increases in Aluminum. *Can. J. Fish. Aquat. Sci.* 52(4): 816-827.

Dickson, W. 1978. Some Effects of the Acidification of Swedish lakes. *Verh. Int. Ver. Limnol.* 20: 851-856.

Driscoll, C, J. Baker, J. Bisogni, and C. Schofield. 1980. Effects of Aluminum Speciation on Fish in Dilute Acidified Waters. *Nature* 284: 161-164.

Driscoll, C.T., Letterman, R.D., 1988. Chemistry and Fate of Al(III) in Treated Drinking Water., J. Eniron. Eng. Div., ACSE 114(1):21-37 (1988).

Earle, Jane; et al. ? Impacts of Mine Drainage on Aquatic Life, Water Uses, and Man-Made Structures. *Deleterious Effects of Mine Drainage.* Chapter 4.

Eaton, J.G., W. A. Swenson, J. H. McCormick, T. D. Simonson, K. M. Jensen. 1992. Field and Laboratory Investigation of Acid Effects on Largemouth Bass, Rock Bass, Black Crappie, and Yellow Perch. *Environmental Research Lab.-Duluth, MN.; Wisconsin Univ.-Superior. Lake Superior Research Inst., Wisconsin Dept. of Natural Resources, Monona.* rans. *Trans. of the Am. Fish. Soc.* 121(5): 644-658.

Edzwald, J.K., Van Benschoten, J. E., 1990. Measureing Aluminum During Water Treatment: Methodology and Application. J. AWWA, 82 (5):71-79 (1990).

Elangovan, R., K.N. White, C.R. MCCrohan. 1997. Bioaccumulation of Aluminium in the Freshwater Snail *Lymnaea stagnalis* at Neutral pH. *Environ. Poll.,* 96(1): 29-33.

Ellis. M.M. 1937. Detection and Measurement of Stream Pollution. *Bull. Bur. Fish.* 48:365-437.

Elphick, J.R., C.M. Pidgeon, S.A. Hopkins, K.L. Bergmann, H.C. Bailey, A. Mulhall, and P.N. Hunt. 2004. The Effect of Fluoride on the Toxicity of Aluminum to Two Marine Species. Poster presentation at Society of Environmental Toxicology and Chemistry 25th Annual Meeting Portland, OR.

Everhart, K.H. and R.A. Freeman. 1973. Effects of Chemical Variations in Aquatic Environments. Volume II. Toxic Effects of Aqueous Aluminum to Rainbow Trout. EPA-R3-73-011b. National Technical Information Service. Springfield, VA.

Exley, C. 2000. Avoidance of Aluminum by Rainbow Trout. *Environ. Tox. Chem.* 19(4): 933-939.

Farag, A.M., Woodward, D.F., Little, E.E., Steadman, B., Vertucci, F.A., 1993. The Effects of Low pH and Elevated Aluminum on Yellowstone Cutthroat Trout (*Oncorhynchus clarki bouvieri*): *Environ. Tox. Chem.* 12(4): 719-731.

Fey, D.L., Wirt, L., Besser, J.M., Wright, W.G., 2002. Water Quality and Aquatic Toxicity Data During 2002 Spring Thaw Conditions in the Upper Animas River Watershed, Silverton, Colorado: US Geological Survey, Open File Report 02-488.

Fiss, F. C., R. F. Carline. 1993. Survival of Brook Trout Embryos in Three Episodically Acidified Streams. - Pennsylvania State Univ., University Park. School of Forest Resources. Pennsylvania Cooperative Fish and Wildlife Research Unit, University Park. Corvallis Environmental Research Lab., OR. *Trans. Am. Fish. Soc.,* 122(2): 268-278.

Freda, J., V. Cavdek, and D.G. McDonald. 1990a. Title: Role of Organic Complexation in the Toxicity of Aluminum to *Rana pipiens* Embryos and *Bufo americanus* Tadpoles. *Can. J. Fish. Aquat. Sci.* 47: 217-224.

Freda, J., and D.G. MCDonald. 1990b. Effects of Aluminum on the Leopard Frog, *Rana pipiens*: Life Stage Comparisons and Aluminum Uptake. *Can. J. Fish. Aquat. Sci*, 47: 210-216.

Freda, Joseph. 1991. The Effects of Aluminum and Other Metals on Amphibians. *Environ. Poll.*, 71: 305-328.

Freeman, R.A. and W.H. Everhart. 1971. Toxicity of Aluminum Hydroxide Complexes in Neutral and Basic Media to Rainbow Trout. *Am. Fish. Soc. Trans.* 100(4): 644-658.

Gagen, C., and W.E. Sharpe. 1987. Net Sodium Loss and Mortality of Three Salmonid Species Exposed to a Stream Acidified by Atmospheric Deposition. *Bull. Environ. Contam. Toxicol.*, 39: 7-14.

Gagen, C.J., W.E. Sharpe, and R.F. Carline. 1993. Mortality of Brook Trout, Mottled Sculpins, and Slimy Sculpins During Acidic Episodes. *Trans. Am. Fish. Soc.* 122(4): 616-628.

Gardner, M.J., E. Dixon, I. Sims, and P. Whitehouse. 2002. Importance of Speciation in Aquatic Toxicity Tests With Aluminum. *Bull Environ Contam Toxicol.* Feb 68(2):195-200.

Gardner, M.J., Gunn, A.M., 1991. Bioavailability of Al from Food and Drinking Water., Proc. Royal Soc. Med. Round Table Series: Alzheimers's Diseases and the Environment,, London, U.K., 1991

Gensemer, R.W. and R.C. Playle. 1999. The Bioavailability and Toxicity of Aluminum in Aquatic Environments. *Cri. Rev. Environ. Science Tech.*, 29(4): 315-450.

Gibson, W.A.C. 1986. The Effect of Calcium on the Toxicity of Aluminum to Freshwater Fish at pH 4.8 and 5.1. Presented at SCL/SIL meeting (Organism-Metal Interactions), Ottawa, January 8, 1986.

Goss, G.G., C.M. Wood. 1988. The Effects of Acid and Acid/Aluminum Exposure on Circulating Plasma Cortisol Levels and Other Blood. *J. Fish Bio.*, 32(1): 63-76.

Gostomski, F. 1990. The Toxicity of Aluminum to Aquatic Species in the US. *Environ Geochem Health* 12: 51-54.

Great Lakes Environmental Center. 1997. Report: Water-Effect Ratio Determination for Aluminum at Fly Ash Run. *In Support of the Development of Site-Specific Criteria at the Albright Power Station Ash Disposal Site Albright, West Virginia.*

Guerold, F., L. Giamberini, J.L. Tourmann, J.C. Pihan, R. Kaufmann. 1995. Occurrence of Aluminum in Chloride Cells of *Perla marginata* (Plecoptera) After Exposure to Low pH and Elevated Aluminum Concentration. *Bull. Environ. Contam. Tox.*, 54(4): 620-625.

Gundersen, D.T., S. Bustaman, W.K. Seim, L.R. Curtis. 1994. pH, Hardness, and Humic Acid Influence on Aluminum Toxicity to Rainbow Trout (*Oncorhynchus mykiss*) in Weakly Alkaline Waters. *Can. J. Fish. Aquat. Sci.*, 51: 1345-1355.

Gunn, J.M. and W. Keller. 1984. Spawning Site Wwater Chemistry and Lake Trout (*Salvelinus namaycush*) Sac Fry Survival During Spring Snowmelt. *Can. J. Fish. Aquat. Sci.* 41: 319-329.

Gunn, J.M. and W. Keller. 1984. *In situ* Manipulations of Water Chemistry Using Crushed Limestone and Observed Effects on Fish. *Fisheries* 9(1):19-24.

Haines, Terry A.. 1981. Acidic Precipitation and its Consequences for Aquatic Ecosystems: A Review. *Tran. Am. Fish. Soc.*, 110: 669-707.

Hall, Jr., L. W., A.E. Pinkney, L.O. Horseman, and S.E. Finger. 1985. Mortality of Striped Bass Larvae in Relation to Contaminants and Water Quality in a Chesapeake Bay Tributary. *Trans. Am. Fish. Soc.*, 114: 861-868.

Hall, W.S. and L.W. Hall Jr. 1989. Toxicity of Alum Sludge to *Ceriodaphnia dubia* and *Pimephales promelas.* Bull. Environ. Contam. Toxicol. 42: 791-798.

Hamilton, S.J., T.A. Haines. 1995. Influence of Fluoride on Aluminum Toxicity to Atlantic Salmon (*Salmo salar*). *Can. J. Fish. Aquat. Sci.*, 52(11): 2432-2444.

Havas, Magda and T. C. Hutchinson. 1982. Aquatic invertebrates from the Smoking Hills N.W.T.: effect of pH and metals on mortality. *Can. J. Fish. Aquat. Sci.* 39(6): 890-903.

Havas, M. and G.E. Likens. 1985a. Changes in ^{22}Na Influx and Outflux in *Daphnia magna* (Straus) as a Function of Elevated Al Concentrations in Soft Water at Low pH. *Proc. Natl. Acad. Sci. U. S. A.* 82: 7345-7349.

Havas. M. and G.E. Lilkens. 1985b. Toxicity of Aluminum and Hydrogen Ions to *Daphnia catawba, Holopedium gibberum, Chaoborus puncipennis,* and *Chironomus anthrocinus.* Mirro Lake, New Hampshire. *Can. J. Zool.* 63: 1114-1119.

Havas, M. 1985c. Aluminum bioaccumulation and toxicity to *Daphnia magna* in soft water at low pH. *Can.J. Fish. Aquat. Sci.* 42:1741-1748.

Henriksen, A., O.K. Skogheim, and B.O. Rosseland. 1984. Episodic Changes in pH and Aluminum Speciation Kill Fish in a Norwegian Salmon River. *Vatten* (2): 255-260.

Henry, T.B., E.R. Irwin, J.M. Grizzle, M.L.Wildhaber, W.G. Brumbaugh. 1999. Acute Toxicity of an Acid Mine Drainage Mixing Zone to Juvenile Bluegill and Largemouth Bass. *Trans. Am. Fish. Soc.*,128(5): 919-928.

Henry, T.B., E.R. Irwin, J.M. Grizzle, M.L.Wildhaber, W.G. Brumbaugh. 2001. Gill Lesions and Death of Bluegill in an Acid Mine Drainage Mixing Zone. *Environ. Tox. Chem.* 20(6): 1304-1311.

Holtze, K.E. 1983. Effects of pH and Ionic Strength on Aluminum Toxicity to Early Developmental Stages of Rainbow Trout (*Salmo gairdneri* Richardson). Ontario Ministry of the Environment, Rexdale, Ontario. Canada.

Horne, M.T., W.A. Dunson. 1994. Exclusion of the Jefferson Salamander, *Ambystoma jeffersonianum*, from Some Potential Breeding Ponds in Pennsylvania: Effects of pH, Temperature, and Metals on Embryonic Development. *Arch. Environ. Contam. Tox.*, 27(3): 323-330.

Horne, M.T., W.A. Dunson. 1995. Effects of Low pH, Metals, and Water Hardness on Larval Amphibians. *Arch. Environ. Contam. Tox*, 29(4): 500-505.

Horne, M.T., W.A. Dunson. 1995. Toxicity of Metals and Low pH to Embryos and Larvae of the Jefferson Salamander, *Ambystoma jeffersonianum. Arch. Environ. Contam. Tox.*, 29(1): 110-114.

Horstrom, E., A. Harbom, F. Edberg, C. Andren. 1995. The Influence of pH on Aluminium Toxicity in the Phytoplankton Species *Monoraphidium dybowskii and M. griffithii. Water, Air Soil Poll.*, 85(2): 817-822.

Hughes, G.M. 1993. Effect of Low Environmental pH in the Presence of Aluminum on Filtration Properties of the Blood of Atlantic Salmon (*Salmo salar* L.). *Acta Biologica Hungarica*, 44(2/3): 223-230.

Hunn, J.B., L. Cleveland and E.E. Little. 1987. Influence of pH and Aluminum on Developing Brook Trout in a Low Calcium Water. *Environ. Pollut.* 43: 63-73.

Hunter, J.B., S.F. Ross, and J. Tannahill. 1980. Aluminum Pollution and Fish Toxicity. *Water Pollut. Control* 79: 413-420.

Ingersoll, C.G., D.R. Mount, D.D. Gulley, T.W. LaPoint, and H.L. Bergman. 1990. The Effects of pH, Aluminum, and Calcium on Survival and Growth of Eggs and Fry of Brook Trout (*Salvelinus fontinalis*). *Can. J. Fish. Aquat. Sci.* 47: 1580-1592.

Ingersoll, C.G., D.D. Gulley, D.R. Mount, J.R. Hockett, M.E. Mueller, and H.L. Bergman. 1990. Aluminum and Acid Toxicity to Two Strains of Brook Trout (*Salvelinus fontinalis*). *Can. J. Fish. Sci.*, 47: 1641-1648.

Jagoe, C.H., T.A. Haines. 1997. Changes in Gill Morphology of Atlantic Salmon (*Salmo salar*) Smolts due to Addition of Acid and Aluminum to Stream Water. *Environ. Poll.,* 97(1/2): 137-146.

Jones. J.R.E. 1939. The Relation Between the Electrolytic Solution Pressures of the Metals and Their Toxicity to the Stickleback (*Gasterosteus aculeatus* L.). *J. Exp. Biol.* 16: 425-437.

Jones, J.R.E. 1940. A Further Study of the Relation Between Toxicity and Solution Pressure, with *Polycelis nigra* as Test Animal. *J. Exp. Biol.* 17: 408-415.

Joseph, E.M., F.M.M. Morel, N.M. Price. 1995. Effects of Aluminum and Fluoride on Phosphorus Acquisition by *Chlamydomonas reinhartdtii. Can. J. Fish. Aquat. Sci.*, 52(2): 353-357.

Keener, A.L. and W.E. Sharpe. 2005. The Effects of Doubling Limestone Sand Applications in Two Acidic Southwestern Pennsylvania Streams. *Restoration Ecology* 13(1): 108-119.

Kimball. G. Manuscript. The Effects of Lesser Known Metals and One Organic to Fathead Minnows (*Pimephales promelas*) and *Daphnia magna*. University of Minnesota. St. Paul, MN.

Kimmel, W.G., and D.J. Murphey. 1985. Macroinvertebrate Community Structure and Detritus Processing Rates in Two Southwestern Pennsylvania Streams Acidified by Atmospheric Deposition. *Hydrobiologia*, 124: 97-102.

Klauda, R.J., R.E. Palmer. 1987. Responses of Blueback Herring Eggs and Larvae to Pulses of Acid and Aluminum. *Trans Am Fish Soc.* 116: 561-569.

Klauda, R.J., R.E. Palmer, M.J. Lendevich. 1987. Sensitivity of Early Life Stages of Blueback Herring to Moderate Acidity and Aluminum in Soft Freshwater. *Estuaries.* 10: 44-53.

Kong, F., Y. Liu, and F. Cheng. 1997. Aluminum Toxicity and Nutrient Utilization in the Mycorrhizal Fungus *Hebeloma mesophacus. Bull Environ Contam Toxicol.* Jul 59(1):125-31.

Khangarot, B.S. and P.K. Ray. 1989. Investigation of Correlation Between Physicochemical Properties of Metals and Their Toxicity to the Water Flea *Daphnia magna* Straus. *Ecotox. Environ. Safety* 18: 109-120.

Khangarot, B.S. 1991. Toxicity of Metals to a Freshwater Tubificid Worm, *Tubifex tubifex* (Muller). *Bull. Environ. Contam. Toxicol.* 46: 906-912.

Khangarot, B.S., R.S. Rathore, and B.B. Singh. 2003. PH-dependent Toxicity of Heavy Metals to a Freshwater Sludgeworm *Tubifex tubifex* Muller. *Bull Environ Contam Toxicol.* Aug 71(2): 283-289.

Laitinen, M., T. Valtonen. 1995. Cardiovascular, Ventilatory and Haematological Responses of Brown Trout (*Salmo trutta* L.), to the Combined Effects of Acidity and Aluminium in Humic water at winter temperature *Aquatic Tox.*, 31(2): 99-112.

Lamb, D.S. and G.C. Bailey. 1981. Acute and Chronic Effects of Alum to Midge Larva (Diptira: Chironomidae). *Bull. Environ. Contam. Toxicol.* 27: 59-67.

Lawlor, A.J.; et al. 2003. Metals in Bulk Deposition and Surface Waters at two Upland Locations in Northern England. *Environmental Pollution*, 121:153-167.

Lawrence, G.B.; et al. 1988. Hydrologic Control of Aluminum Chemistry in an Acidic Headwater Stream. *Water Resources Research*, 24(5): 659-669.

Leino, R.L., J.H. MCCormick, K.M. Jensen. 1990. Multiple Effects of Acid and Aluminum on Brood Stock and Progeny of Fathead Minnows, With Emphasis on Histopathology. *Can. J. Zool*, 68: 234-244.

Leino, R.L., J.H. MCCormick. 1993. Response of Juvenile Largemouth Bass to Different pH and Aluminium Levels at Overwintering Temperatures: Effects on Gill Morphology, Electrolyte Balance, Scale Calcium, Liver Glycogen, and Depot Fat. *Can. J. Zool.* 71(3): 531-543.

Li, X., F. Zhang. 1992. Toxic Effects of Low pH and Elevated Al Concentration on Early Life Stages of Several Species of Freshwater Fishes *Huanjing Kexue Xuebao*, 12(1): 97-104.

Lydersen, E.. S. Oxnevad, K. Ostbye, R.A. Andersen, F. Bjerkely, L.A. Vollestad, and B.S. Poleo. 2002. The Effects of Ionic Strength on the Toxicity of Aluminum to Atlantic Salmon (*Salmo salar*) Under Non-Steady State Chemical Conditions. *J. Limnol*, 61(1): 69-76.

Mackie, G.L. 1989. Tolerances of Five Benthic Invertebrates to Hydrogen Ions and Metals (Cd, Pb, Al) *Arch. Environ. Contam. Toxicol*, 18(1-2): 215-223.

Malley, D.F. and P.S.S. Chang. 1985. Effects of Aluminum and Acid on Calcium Uptake by the Crayfish *Orconestes virilis. Arch. Environ. Contam. Toxicol.* 14: 739-747.

Maltby, L., M. Crane. 1994. Responses of *Gammarus pulex* (Amphipoda, Crustacea) to Metalliferous Effluents: Identification of Toxic Components and the Importance of Interpopulation Variation. *Environ. Poll.*, 84(1): 45-52.

Martin, T.R. and D.M. Holdich. 1986. The Acute Lethal Toxicity of Heavy Metals to Percacarid Crustaceans (with Particular Reference to Fresh-Water Asellids and Gammarids). *Wat. Res.* 20(9): 1137-1147.

McCormick, J.H., K.M. Jensen, L.E. Anderson. 1989. Chronic Effects of Low pH and Elevated Aluminum on Survival, Maturation, Spawning and Embryo-Larval Development of the Fathead Minnow in Soft Water. *Water, Air and Soil Pollution*, 43(3-4): 293-307.

McCormick, J.H., K.M. Jensen. 1992. Osmoregulatory Failure and Death of First-Year Largemouth Bass (Micropterus salmoides) Exposed to Low pH and Elevated Aluminum, at Low Temperature in Soft Water. *Can. J. Fish. Aquat. Sci*, 49(6): 1189-1197.

McCauley. D.J., L.T. Brooke. D.J. Call and C.A. Lindberg. 1986. Acute and chronic toxicity of aluminum to *Ceriodaphnia dubia* at various pH's. University of Wisconsin-Superior, Superior, WI.

McDonald, D.G, C.M. Wood, R.G. Rhem, M.E. Mueller, D.R. Mount, and H.L. Bergman. 1991. Nature and Time Course of Acclimation to Aluminum in Juvenile Brook Trout (*Salvelinus fontinalis*). I. Physiology. *Can. J. Fish. Aquat. Sci.*, 48: 2006-2015.

Merrett, W.J., G.P. Rutt, N.S. Weatherley, S.P. Thomas, and S.J. Ormerod. 1991. Title: The Response of Macroinvertebrates to Low pH and Increased Aluminium Concentrations in Welsh Streams: Multiple Episodes and Chronic Exposure. *Arch. Hydrobiol.* 121(1): 115-125.

Mount, D.R., C.G. Ingersoll, D.D. Gulley, J.D. Fernandez, T.W. LaPoint, and H.L. Bergman. 1988. The Effect of Long-Term Exposure to Acid, Aluminum, and Low Calcium on Adult Brook Trout (*Salvelinus fontinalis*). 1. Survival, Growth, Fecundity, and Progeny Survival. *Can. J. Fish. Aquat. Sci.* 45: 1623-1632.

Mount, D.R., C.G. Ingersoll, D.D. Gulley, J.D. Fernandez, T.W. LaPoint, and H.L. Bergman. 1988. The Effect of Long-Term Exposure to Acid, Aluminum, and Low Calcium on Adult Brook Trout (*Salvelinus fontinalis*). 2. Vitellogenesis and Osmoregulation. *Can. J. Fish. Aquat. Sci.* 45: 1633-1642.

Mount, D.R., M.J. Swanson, J.E. Breck, A.M. Farag, and H.L. Bergman.1990. Responses of Brook Trout (*Salvelinus fontinalis*) Fry to Fluctuating Acid, Aluminum, and Low Calcium exposure. *Can. J.Fish. Aquat. Sci.* 47: 1623-1630.

Muniz, I.P. and H. Leivestad. 1980. Acidification - Effects on Fresh-Water Fish. Proc. Int. Conf. Ecol. Impact Acid Precip., Norway, 1980, SNSF Project.

Muranoto, S. 1981. Influence of Complexans (NTA, EDTA) on the Toxicity of Aluminum Chloride and Sulfate to Fish at High Concentrations. *Bull. Environ. Contam. Toxicol.* 27: 221-225.

Myllynen, K., E. Ojutkangas, M. Nikinmaa. 1997. River Water with High Iron Concentration and Low pH Causes Mortality of Lamprey Roe and Newly Hatched Larvae *Ecotox. Environ. Safety,* 36: 43-48.

Nalewajko, C. and B. Paul. 1985. Effects of Manipulation of Aluminum Concentrations and pH on Phosphate Uptake and Photosynthesis of Planktonic Communities in Two Precambrian Shield Lakes. *Can. J. Fish. Aquat. Sci.* 42: 1946-1953.

Neville, CM. 1985. The Physiological Response of Juvenile Rainbow Trout, *Salmo gairdneri*, to Acid and Aluminum - Prediction of Field Responses From Laboratory Data. *J. Can. Fish. Aquat. Sci.* 42: 2004-2019.

Norrgren, L., E. Degerman. 1993. Effects of Different Water Qualities on the Early Development of Atlantic Salmon and Brown Trout Exposed In Situ. *Ambio: a journal of the human environment,* 22(4): 213-218.

Odonnell, A.R., G. Mance, and R. Norton. 1984. A Review of the Toxicity of Aluminum in Fresh Water. WRC Environment, Medmenham Laboratory England. Technical Report TR197, 27 p.

Ogilvie. D.M. and D.M. Stechey. 1983. Effects of Aluminum on Respiratory Responses and Spontaneous Activity of Rainbow Trout, *Salmo gairdneri. Environ. Toxic. Chem.* 2: 43-48.

Olson, D.L. and G.M. Christensen. 1980. Effects of Water Pollutants and Other Chemicals on Fish Acetyleholinesterase (in vitro). *Environ. Res.* 21: 327-335.

Orr, P. L., R. W. Bradley, J. B. Sprague, and N. J. Hutchinson. 1986. Acclimation-Induced Change in Toxicity of Aluminum to Rainbow Trout (*Salma gairdneri*) *Can. J. Fish. Aquat. Sci.* 43: 243-246.

Palmer, R.E., R.J. Klauda, M.A. Jepson, and E.S. Perry Publication. 1989. Acute Sensitivity of Early Life Stages of Fathead Minnow (*Pimephales promelas*) to Acid and Aluminum. *Water Res.* 23(8): 1039-1047.

Palmer, Sheila M.; et al. 2002. Decline in Mobilization of Toxic Aluminum. *Nature,* 417(6886):242-243.

Parkhurst, B.R., H.L. Bergman, J. Fernandez, D.D. Gulley, J.R. Hockett, and D.A. Sanchez. 1990. Inorganic Monomeric Aluminum and pH as Predictors of Acidic Water Toxicity to Brook Trout *(Salvelinus fontinalis). Can. J. Aquat. Sci.* 47:1631-1640.

Pauli, Bruce. 1998. Threats to Amphibians: pH/Metal Toxicities. *www.ice.ucdavis.edu.*

Perakis, S.S., E.B. Welch, J.M. Jacoby. 1996. Sediment-to-Water Blue-Green Algal Recruitment in Response to Alum and Environmental Factors *Hydrobiologia*, 318(3): 165-177.

Peterson. S.A., W.D. Sanville. F.S. Stay and C.F. Powers. 1974. Nutrient Inactivation as a Lake Restoration Procedure. Laboratory investigations. EPA-660/3-74-032. National Technical Information Service, Springfield, VA.

Peuranen, S., P.J. Vuorinen, M. Vuorinen, H. Tuurala. 1993. Effects of Acidity and Aluminium on Fish Gills in Laboratory Experiments and in the Field. *Sci Total Environ Pt, 2:* 979-988.

Peuranen, Seppo; et al. 2003. Effects of Temperature on the Recovery of Juvenile Grayling (*Thymallus thymallus*) from Exposure to Al + Fe. *Aquatic Toxic.*, 65: 73-84.

Poleo, A.B.S., I.P. Muniz. 1993. The Effect of Aluminium in Soft Water at Low pH and Different Temperatures on Mortality, Ventilation Frequency and Water Balance in Smoltifying.. *Biology of Fishes*, 36(2): 193-203.

Poleo, A.B.S., S.A. Oxneyad, K. Ostbye, R.A. Andersen, D.H. Oughton, L.A. Vollestad. 1995. Survival of Crucian Carp, *Carassius carassius*, Exposed to a High Low-Molecular Weight Inorganic Aluminium Challenge. *Aquatic Sciences*, 57(4): 350-359.

Poléo, A.B.S, E. Lydesen, B.O. Rosseland, F.Kroglund, B. Salbu, R.D. Vogt and A. Kvellestad. 1994. Increased Mortality of Fish Due to Changing Al-Chemistry of Mixing Zones Between Limed Streams and Acidic Tributaries. *Water, Air, Soil Poll.*, 75: 339-351.

Poleo, A.B.S., K. Ostbye, S.A. Oxnevad, R.A. Andersen, E. Heibo, L.A. Vollestad. 1997. Toxicity of Acid Aluminium-Rich Water to Seven Freshwater Fish Species: A Comparative Laboratory Study. *Environ. Poll.*, 96(2): 129-139.

Pynnonen, K., 1990 Aluminium Accumulation and Distribution in the Freshwater Clams (Unionidae). *Comp. Biochem. Phys.* 97 C(1): 111-117.

Rai, L.C., Y. Husaini, N. Mallick. 1998. pH-Altered Interaction of Aluminium and Fluoride on Nutrient Uptake, Photosynthesis and Other Variables of *Chlorella vulgaris*. *Aquatic Toxicology*, 42(1): 67-84.

Rao. V.N.R. and S.K. Subramanian. 1982. Metal Toxicity Tests on Growth of Some Diatoms. *Acta Bot. Indict* 10: 274-281.

Rayburn, J.R. and R.K. Aladdin. 2003. Developmental Toxicity of Copper, Chromium, and Aluminum Using the Shrimp Embryo Teratogenesis Assay: Palaemonid with Artificial Seawater. *Bull Environ Contam Toxicol.* Sep 71(3): 481-8.

Reash, R.J., R.E. Lockwood, and Belviso. 2003. Toxicity Identification Evaluation of a Coal Ash Effluent: Assessment of Watershed Mine Drainage Influence. In Preceedings of Society of Environmental Toxicology and Chemistry 24th Annual Meeting Austin, TX 2003.

Rosseland, B.O. 1980. Physiological responses to acid water in fish. 2. Effects of Acid Water on Metabolism and Gill Ventilation in Brown Trout, *Salmo trutta* (L.), and Brook Trout, *Salvelinus fontinalis* (Mitchell). Proc. Int. Conf. Impact. Acid Precip., Norway, 1980, SNSF Project.

Rosseland, B.O., and O.K. Skogheim. 1982. Physiological Stress and Mortality of Atlantic salmon, *Salmo salar* L. in Acid Water with High Levels of Aluminum. Proc. of Council Meeting, 1982, of the International Council for the Exploration of the Sea. Copenhagen, Denmark. 16 p.

Rosseland, B.O.; et al. 1992. The Mixing Zone Between Limed and Acidic River Waters: Complex Aluminum Chemistry and Extreme Toxicity for Salmonids. *Environ. Poll.*, 78:3-8.

Roy, R.L. and P.G.C. Campbell. 1997. Decreased Toxicity of Al to Juvenile Atlantic Salmon (*Salmo Salar*) in Acidic Soft Water Containing Natural Organic Matter: A Test of the Free-Ion Model. *Environ. Tox. Chem.* 16(9): 1962-1969.

Ruthven. J.A. and J. Cairns, Jr. 1973. Response of Fresh-Water Protozoan Artificial Communities to Metals. *J. Protozool.* 20: 127-135.

Sadler, K., and S. Lynam. 1988. The Influence of Calcium on Aluminum-Induced Changes in the Growth Rate and Mortality of Brown Trout, *Salmo trutta L. J. Fish Biol.*, 33: 171-179.

Sanborn, N.H. 1945. The Lethal Effect of Certain Chemicals on Fresh Water Fish. *Canner*. pp. 13-15.

Schofield, C, and J. Trojnar. 1980. Aluminum toxicity to brook trout (*Salvelinus fontinalis*) in acidified waters. In. Toribara, M. Miller, and P. Morrow, (editors). Polluted rain. Plenum Press, New York, New York. USA. Pages 341-366.

Segner, H., H. Gebhardt, M. Linnenbach, R. Marthaler, A. Ness. 1991. Influence of Low pH on Brown Trout, *Salmo trutta. Verh Int Ver Limnol*, 24: 2470-2473.

Sharpe, Williams E.; et al. 1987. Status of Headwater Benthic Insect Populations in an Area of High Hydrogen Ion and Sulfate Deposition. *Northeastern Environmental Science*, 6(1): 23-30.

Simmons, Jeffrey A. 2004 draft. Synergistic Toxic Effects of Zn, Cu, Pb, Al, and Mn on *Lemna minor: Excerpts, Biology Department, WV Wesleyan College, Buckhannon, WV; simmons@wvwc.edu.*

Simonin, H., W.A. Kretser, D.W. Bath, M. Olson, and J. Gallagher. 1993. *In Situ* Bioassays of Brook Trout (*Salvelinus fontinalis*) and Blacknose Dace (*Rhinichthys atratulus*) in Adirondack Streams Affected by Episodic Acidification. *Can. J. Fish Aquat. Sci.*, 50: 902-912.

Skogheim, O.K. and B.O. Rosseland. 1986. Mortality of Smolt of Atlantic Salmon, *Salmo salar* L., at Low Levels of Aluminium in Acidic Softwater. *Bull Environ Contam Toxicol.* Aug 37(2):258-65.

Smith, T.R. and T. Haines. 1995. Mortality, Growth, Swimming Activity and Gill Morphology of Brook Trout (*Salvelinus fontinalis*) and Atlantic Salmon (*Salmo salar*) Exposed to Low pH With and Without Aluminum. *Environ. Poll.*, 90(1): 33-40.

Snell, T.W., B.D. Moffat, C. Janssen, G. Persoone. 1991. Acute Toxicity Tests Using Rotifers IV. Effects of Cyst Age, Temperature, and Salinity on the Sensitivity of *Barachionus calyciflorus. Ecotoxic. Environ. Safety*, 21(3): 308-317.

Snell, T.W. 1991. New Rotifer Bioassays for Aquatic Toxicology *Final Report, US Army Medical Research and Development Command, Ft Detrick, Frederick, MD*: 29 p (US NTIS AD-A258002). ON MICROFICHE

Snucins, E.J, and B.J. Shuter. 1991. Survival of Introduced Smallmouth Bass in Low-pH Lakes. *Trans. Am. Fish. Soc.*, 120: 209-216.

Soucek, D.J., D.S. Cherry, and G.C. Trent. 2000. Relative Acute Toxicity of Acid Mine Drainage Water column and Sediments to *Daphnia magna* in the Puckett's Creek Watershed, Virginia, USA. Arch. Environ. Contam. Toxicol. 38: 305-310.

Soucek, D.J., D.S. Cherry, and C.E. Zipper. 2001. Aluminum-dominated Acute Toxicity to the Cladoceran *Ceriodaphnia dubia* in Neutral Waters Downstream of an Acid Mine Drainage Discharge. Can. J. Aquat. Sci. 58: 2396-2404.

Sparling, D.W., and P. Lowe. 1996. Environmental Hazards of Aluminum to Plants, Invertebrates, Fish, and Wildlife. *Reviews of Environ. Contam. Tox.*, 145: 1-127.

Sparling, D. W., T. P. Lowe, and P. G. C. Campbell. 1997. Ecotoxicology of Aluminum to Fish and Wildlife.
In Robert A. Yokel and Mari S. Golub, editors. *Research issues in aluminum toxicity.* Taylor & Francis, Washington, D.C. xi, 256; Pages 47-68.

Stanley, R.A. 1974. Toxicity of Heavy Metals and Salts to Eurasian Watermilfoil (*Yriophyllum sicatus* L.). *Arch. Environ. Contam. Toxicol.* 2: 331-341.

Tandjung, S.D., D.V. Rottiers, R.L. Herman, and M. Godjah. 1982. Histopathological Studies on the Effects of Acid Stress to Brook Trout, *Salvelinus fontinalis* (Mitchell) in the Presence of Sub-lethal Concentration of Aluminum. In: Johnson, R.E. (ed.) Acid rain/fisheries. *Proc. of an International Symposium on Acidic Rain and Fishery Impacts on Northeastern North America*, p.357.

Thomas. A. 1915. Effects of Certain Metallic Salts Upon Fishes. *Trans. Am. Fish. Soc.* 44:120-124.

Truscott, R., C.R. McCrohan, S.E.R. Bailey, K.N. White. 1995. Effect of Aluminium and Lead on Activity in the Freshwater Pond Snail *Lymnaea stagnalis. Can. J. Fish.Aq. Sci.*, 52(8): 1623-1629.

Van Coillie, R., C. Thellen, P.G.C. Campbell and Y. Vigneault. 1983. Effets toxiques de 'aluminium chez les salmonides en relation avec des conditions physico-chimiques acides. *Rapp. tech. can. sci. halieut.*

Van Sickle, J., J.P. Baker, H.A. Simonin, B.P. Baldigo, W.A. Kretser, and W.E. Sharpe. 1996. Episodic Acidification of Small Streams in the Northeastern United States: Fish Mortality in Field Bioassays. *Ecological Applications* 6(2): 408-421.

Verbost, P.M., M.H.G. Berntssen, F. Kroglund, E. Lydersen, H.E. Witters, B.O. Rosseland, B.Salbu. 1995. The Toxic Mixing Zone of Neutral and Acidic River Water: Acute Aluminium Toxicity in Brown Trout (*Salmo trutta* L.) *Water, Air, Soil Poll.* (2): 341-346.

Vuorinen, M., P.J. Vuorinen, J. Hoikka, and S. Peuranen. 1993. Lethal and Sublethal Threshold Values of Aluminium and Acidity to Pike (*Esox lucius*), Whitefish (*Coregonus lavaretus* pallasi), Pike Perch. *Sci.Total Environ.*(Suppl. 1993): 953-967.

Vuorinen, P.J., M. Keinanen, S. Peuranen, and C. Tigerstedt. 2003. Reproduction, Blood and Plasma Parameters and Gill Histology of Vendace (*Coregonus albula L.*) in Long-Term Exposure to Acidity and Aluminum. *Ecotox. Environ.Safety*, 54: 255-276.

Walker, R.L, C.M. Wood, and H.L. Bergman. 1991. Effects of Long-Term Preexposure to Sublethal Concentrations of Acid and Aluminum on the Venitlatory Response to Aluminum Challenge in Brook Trout (*Salvelinus fontinalis*). *Can. J. Fish. Aquat. Sci.*, 48: 1989-1995.

Wallen, I.E., W.C. Greer and R. Lasater. 1957. Toxicity to *Gambusia affinis* of Certain Pure Chemicals in Turbid Waters. *Sewage Ind. Wastes* 29: 695-711.

Wang, Xing. ? Aluminum Mobilization from the Forest Land. *The Roosevelt Wild Life Station, Conservation and Education Research*, esf.edu/resorg/rooseveltwildlife/Resarch/Al/Al.

Weatherley, N.S., A.P. Rogers, X. Goenaga, and S.J. Ormerod Publication. 1990. The Survival of Early Life Stages of Brown Trout (*Salmo trutta* L.) in Relation to Aluminium Speciation in Upland Welsh Streams. *Aquat. Toxicol.* 17(3):213-230.

Wigington, Jr., P.J.; et al. 1996. Episodic Acidification of Small Streams in the Northeastern United States: Episodic Response Project. *Ecological Applications*, 6(2): 374-388.

Williams, P.L., D.B. Dusenbery. 1990. Aquatic Toxicity Testing Using the Nematode, *Caenorhabditis elegans. Environ. Toxic. Chem.*, 9(10): 1285-1290.

Wilson, R.W., C.M. Wood. 1992. Swimming Performance, Whole Body Ions, and Gill Al Accumulation During Acclimation to Sublethal Aluminium in Juvenile Rainbow Trout (*Oncorhynchus mykiss*). *Fish Phys. Biochem.*, 10(2): 149-159.

Wilson, R.W., H.L. Bergman, C.M. Wood. 1994. Metabolic Costs and Physiological Consequences of Acclimation to Aluminum in Juvenile Rainbow Trout (*Oncorhynchus mykiss*). 1: Acclimation *Can. J. Fish. Aquat. Sci*, 51: 527-535.

Wilson, R.W., H.L. Bergman, C.M. Wood. 1994. Metabolic Costs and Physiological Consequences of Acclimation to Aluminum in Juvenile Rainbow Trout (*Oncorhynchus mykiss*). 2: Gill Morphology.. *Can. J. Fish. Aquat. Sci*, 51(3): 536-544.

Wilson, R.W., C.M. Wood, D.F. Houlihan. 1996. Growth and Protein Turnover During Acclimation to Acid and Aluminum in Juvenile Rainbow Trout (*Oncorhynchus mykiss*). *Can. J. Fish. Aquat. Sci.*, 53(4): 802-811.

Witters, H.E., S. Van Puymbroeck, A.J.H. Stouthart, S.E. Wendelaar Bonga. 1996. Physicochemical Changes of Aluminium in Mixing Zones: Mortality and Physiological Disturbances in Brown Trout (*Salmo trutta* L.) *Environ. Tox. Chem.*, 15(6): 986-996.

Wooldridge, C.R. and D.P. Wooldridge. 1969, Internal Damage Aquatic Beetle Exposed to Sublethal Concentrations of Inorganic Ions. *Ann. Entomol. Soc. Am.* 62: 921-922.

Wood, C.M.; et al. 1988. Physiological Evidence of Acclimation to Acid/Aluminum Stress in Adult Brook Trout (*Salvelinus fontinalis*). 2. Blood Parameters by Cannulation. *Can. J. Fish. Aquat. Sci.*, 45:1597-1605.

Wood, C.M., D.G. McDonald, C.G. Ingersoll, D.R. Mount, D.E. Johannsson, S. Landsberger, and H.L. Bergman. 1990. Effects of Water Acidity, Calcium, and Aluminum on Whole Body Ions of Brook Trout (*Salvelinus fontinalis*) Continuously Exposed From Fertilization to Swim-up: a Study by Instrumental Neutron Activation Analysis. *Can. J. Fish. Aquat. Sci.* 47: 1593-1603.

Wood, C.M., D.G. McDonald, C.G. Ingersoll, D.R. Mount, D.E. Johannsson, S. Landsberger, and H.L. Bergman. 1990. Whole Body Ions of Brook Trout Alevins: Responses of Yolk-sac and Swim-up Stages to Water Acidity, Calcium, and Aluminum, and Recovery Effects. *Can. J. Fish. Aquat. Sci.* 47: 1604-1615.

Woodward, D.F., Farag, A.M., Little, E.E., Steadman, B., Yancik, R., 1991, Sensitivity of Greenback Cutthroat Trout to Acidic pH and Elevated Aluminum: *Trans .of the Am. Fish. Soc.* 120(1): 34-42.

Woodward, D.F., Farag, A.M., Mueller, M.E., Little, E.E., Vertucci, F.A., 1989, Sensitivity of Endemic Snake River Cutthroat Trout to Acidity and Elevated Aluminum: *Trans .of the Am. Fish. Soc.* 118(6): 630-643.

ATTACHMENT 2

Checklist

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Attachment 2

Checklist for Test Acceptability for Criteria Development

Study author/title: ____

For use in development of ____

Data Quality Requirements as per 1985 EPA *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms,* **40 CFR 132 Appendix A, and** ASTM 2004.

Is Requirement met?

Yes No NI[2] Requirement

Yes	No	NI	Requirement
			Data are available in a typed, dated and signed copy form and available for distribution (A)
			The test must contain a control treatment in which most (90%- EPA) of the control organisms show no signs of stress disease or death. (A, C (729 Sec 13), D)
			The dilution water used should not be distilled or deionized water without the addition of appropriate salts. (A)
			Data on technical grade materials may be used if appropriate, but data on formulated mixtures and emulsifiable concentrates of the material shall not be used. . (A,C (729 Sec 9))
			If chemical of concern is volatile, hydrolyzable, or degradable; it may be appropriate to use only results of flow-through tests in which the concentrations of test material in test solutions were measured using acceptable analytical methods. (A)
			The species being used for testing must have reproducing wild populations in North America. See Appendix 1 of USEPA 1985 Guidance. (A)
			Test organisms that were previously exposed to substantial concentrations of the test material or other contaminants should not be used. (A)
			Results of acute tests during which the test organisms were fed should not be used, unless data indicate that the food did not affect the toxicity of the test material. . (A,C (729 Sec 11.6))
			Results of acute tests conducted in unusual dilution water, for example, dilution water in which total organic carbon or particulate matter exceeded 5mg/L shall not be used, unless data show that the organic carbon or particulate matter do not affect toxicity. (A)
			Tests with daphnid or other cladoceran species must be started with organisms <24 hr old. (A, C (729 Sec 10), D)
			Tests with midges must be started with second or third instar larvae. . (A, C (729 Sec 10), D)
			48-hr EC50 or 48-hr LC50 acute statistical endpoints are preferred for cladocerans, 96-hr EC50/LC50 for bivalves, crabs, shrimp and 96-hr EC50/LC50 for all other species. Longer than 48-hr data (cladocerans) can be used as long as the controls are acceptable and organisms were not fed. (A, C (729 Sec 11.7-8), D)
			If the acute values available for a species or genus differ by more than a factor of 10, rejection of some or all of the values would be appropriate. (A)
			Saltwater species data should not be used to calculate freshwater criteria (except in deriving ACR). (B)

Other Data Quality Requirements

Yes	No	NI	Requirement
			If using fish species, it is preferred that the test by started using juvenile, or newly hatched fish.(C (729 Sec 10.2), D)
			Test organisms of uniform size and from the same source. (C (729 Sec 10.2), D)
			All test chambers are identical. (C (729 Sec 13.1))
			There are >10 organisms at each test concentration for static or renewal tests and >20 organisms per test concentration for flow-through test. (C (729 Sec 11.1), D)
			Organisms are randomly assigned to test chambers. (C (729 Sec 15.5))
			Treatments are randomly assigned to individual test chambers. (C (729 Sec 11.1))
			Dissolved oxygen is maintained at 60-100% for the first 48 hrs and at 40-100% after 48 hrs. (C (729 Sec 11.2))
			The test temperature in the proper range. (C (729 Sec 11.3), D)
			If chemical of concern is volatile or degradable, sufficient chemical measurements are made to ensure test concentrations do not drop by more than 20%. (C (729 Sec 11.9))
			Test organisms have not been treated for disease during or within 10 days of the test initiation. (C (729 Sec 10.6))
			Calculation of an LC50 or EC50 is unacceptable if 1) no treatment other than a control treatment killed or affected <37% of the test organisms exposed to it, or 2) no treatment killed or affected >63% of the organisms exposed to it. (C (729 Sec

2 No or insufficient information was given in the article to determine if requirement was met.

			13.2))
			There are at least 2 test chambers per concentration. (C (729 Sec 11.1), D)
			The photoperiod is 16hr light, 8 hr dark, with ambient lighting at 50-100 ft-c. (D)
			The test is started with the test solutions at pH 6-9s.u. and a DO near saturation but not supersaturated. (D)
			At a minimum, at the start of the test, the pH, conductivity and TRC of the effluent or test water is measured. At a minimum, at the start of the test, the pH and conductivity of the dilution water is measured. (D)
			The test is started within the appropriate holding times. (effluent: 72hrs, receiving water: 96hr) (D)
			The effluent and receiving water (if not lab reconstituted) is held at 4 deg C following collection until the test set up. (D)
			The test organisms have not been subjected to a change in temperature of 3 deg C on more during a 12hr period. (C (729 Sec 10.8), D
			A reference toxicant test was performed on same lot of test species within the last 5 months. (C (729 Sec 10.9), D)
			If test organisms are feral, they were observed in the laboratory for at least 1 week prior to use (to assure organisms are free of signs of adverse effects) (D)
			The test temperature was started and maintained at appropriate levels +/- 1 degree. (20deg C or 25deg C for Daphnids, minnows, 12deg C for trout) (C (729 Sec 11.3), D)
			Where acute toxicity test methods are utilized to determine permit limits for toxic chemicals, at a minimum, the concentration of the test material must be measured in each test concentration at test initiation, daily thereafter, and at test termination. (D)
			The LC50/EC50 is determined by the Graphical, Spearman-Karber, Trimmed Spearman-Karber, or Probit Method using 95% confidence limits. (D)

____ ____ **IS THIS TEST ACCEPTABLE FOR USE IN DEVELOPING AN ACUTE CRITERION?**

REQUIREMENTS FOR CHRONIC TEST DATA ACCEPTABILITY

(as per USEPA 1985 Guidance and in addition to the applicable requirements above)

			Chronic data should be based on results of flow-through (except for Daphnids) chronic tests. (A)
			Concentrations of test material are properly measured in test solutions at appropriate times during test. (A)
			Control survival, growth, or reproduction must be within acceptable limits (limits depend on species). (A)
			Chronic values should be based on endpoints and exposure durations appropriate to the species. Only the following kinds of chronic tests should be used:
			• Life-cycle: exposure to toxicant throughout a life cycle. Test should start with embryos or newly hatched young (fish), test end no less than 24 days after next generation hatching (90 days for salmonids). Daphnid tests should begin with <24hr old young and last for no less than 21 days. Endpoints based on survival, growth, adult maturation, eggs spawned per female, embryo viability (salmonids only) and hatchability for fish. For Daphnids, survival and young per female. (A)
			• Partial life-cycle: exposure to toxicant through most of a life cycle. Allowed for fish species requiring more than a year to reach sexual maturity. Tests should begin with immature juveniles, continue through maturation and reproduction and end no less than 24 days after hatching of next generation. Endpoints based on survival, growth, maturation, eggs spawned, embryo viability (slamonid only) and hatchability. (A)
			• Early life-stage: exposure to toxicant shortly after fertilization through embryonic, larval, and early juvenile development (28-32 days, 60 post-hatch for salmonids). Endpoints based on survival and growth only. (A)
			Chronic value can equal the geomean of the lower and upper chronic limits or by regression analysis. (A)

____ ____ **IS THIS TEST ACCEPTABLE FOR USE IN DEVELOPING A CHRONIC CRITERION?**

Test Conditions

Aluminum cmpd tested __________ purity (grade): reagent technical other info _______

Analytical results in TOTAL or DISSOLVED Aluminum? (circle)

Test endpoint concentration in TOTAL or DISSOLVED Aluminum? (circle)

pH __________ Did it change during test? Range __________
Hardness __________ Did it change during test? Range __________
Alkalinity __________ Did it change during test? Range __________
TOC __________ Did it change during test? Range __________
Temperature __________

The following letters correspond to the reference from which the data requirement is stated:

A) Specifically stated in 1985 USEPA *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses*

B) Not specifically stated, but inferred in 1985 USEPA *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses*

C) ASTM section of specific method in parentheses
729 = ASTM E729-96 *Standard Guide for Conducting Acute Toxicity Tests on Test Material with Fishes, Macroinvertebrates, and Amphibians*

D) USEPA WET testing conditions from WET manuals

ATTACHMENT 3

Data Not Usable for Criteria Derivation

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ATTACHMENT 3. ALUMINUM TOXICITY DATA NOT USED IN CRITERIA CALCULATIONS
These studies have endpoints other than LC50, EC50 or TLm

Common Name	Genus species	Form of Aluminum Tested	Toxicity Value	Endpoint (units and Al concentration)	Tox value Total or Dissolved	Duration	Life stage	Test Conditions pH (s.u.)	Hardness (mg/l)	Temp (deg C)	TOC (mg/L)	Reference	Comments
Golden Trout	*Oncorhynchus aguabonita*	$Al_2(SO_4)_3$	0	% survival at 300 ug/L Al	total	7 d	alevin	5	?	10	?	DeLonay et al. 1993	
Golden Trout	*Oncorhynchus aguabonita*	$Al_2(SO_4)_3$	14	% survival at 300 ug/L Al	total	7 d	alevin	4.5	?	10	?	DeLonay et al. 1993	
Brook Trout	*Salvelinus fantinalis*	$AlCl_3$	93	% survival at 162 ug/L Al	total	147 d	adult	5.4	soft	9-14	?	Mount et al. 1988 (1)	Ca = 8 mg/L
Brook Trout	*Salvelinus fantinalis*	$AlCl_3$	93	% survival at 162 ug/L Al	total	147 d	adult	5.5	soft	9-14	?	Mount et al. 1988 (1)	Ca = 2 mg/L
Brook Trout	*Salvelinus fantinalis*	$AlCl_3$	86	% survival at 162 ug/L Al	total	147 d	adult	5.4	soft	9-14	?	Mount et al. 1988 (1)	Ca = 0.5 mg/L
Brook Trout	*Salvelinus fantinalis*	$AlCl_3$	50	% survival at 486 ug/L Al	total	147 d	adult	4.4	soft	9-14	?	Mount et al. 1988 (1)	Ca = 8 mg/L
Brook Trout	*Salvelinus fantinalis*	$AlCl_3$	79	% survival at 486 ug/L Al	total	147 d	adult	4.5	soft	9-14	?	Mount et al. 1988 (1)	Ca = 2 mg/L
Brook Trout	*Salvelinus fantinalis*	$AlCl_3$	36	% survival at 486 ug/L Al	total	147 d	adult	4.4	soft	9-14	?	Mount et al. 1988 (1)	Ca = 0.5 mg/L
Brook Trout	*Salvelinus fantinalis*	$AlCl_3$	57-80	% survival at 191 ug/L Al	total	28 d	1 yr old	4.66	soft	?	?	Ingersol et al. 1990	% survival is range of 3 strains of trout tested
Brook Trout	*Salvelinus fantinalis*	$AlCl_3$	20-42.9	% survival at 665 ug/L Al	total	28 d	1 yr old	4.33	soft	?	?	Ingersol et al. 1990	% survival is range of 3 strains of trout tested
Brook Trout	*Salvelinus fantinalis*	$AlCl_3$	0-14	% survival at 704 ug/L Al	total	28 d	1 yr old	4.32	soft	?	?	Ingersol et al. 1990	% survival is range of 3 strains of trout tested
Brook Trout	*Salvelinus fantinalis*	$Al_2(SO_4)_3$	7.2	% mortality at 300 ug/L Al	total?	eyed to hatch	egg	7.2	256-268	12	?	Cleveland et al. 1986	test duration not appropriate
Brook Trout	*Salvelinus fantinalis*	$Al_2(SO_4)_3$	6.0	% mortality at 300 ug/L Al	total?	eyed to hatch	egg	5.5	256-268	12	?	Cleveland et al. 1986	test duration not appropriate
Brook Trout	*Salvelinus fantinalis*	$Al_2(SO_4)_3$	45.6	% mortality at 300 ug/L Al	total?	eyed to hatch	egg	4.5	256-268	12	?	Cleveland et al. 1986	test duration not appropriate
Brook Trout	*Salvelinus fantinalis*	$Al_2(SO_4)_3$	2.8	% mortality at 300 ug/L Al	total?	15 d	0-30 d old	7.2	256-268	12	?	Cleveland et al. 1986	test duration not appropriate
Brook Trout	*Salvelinus fantinalis*	$Al_2(SO_4)_3$	4.0	% mortality at 300 ug/L Al	total?	30 d	0-30 d old	7.2	256-268	12	?	Cleveland et al. 1986	test duration not appropriate
Brook Trout	*Salvelinus fantinalis*	$Al_2(SO_4)_3$	16	% mortality at 300 ug/L Al	total?	15 d	0-30 d old	5.5	256-268	12	?	Cleveland et al. 1986	test duration not appropriate
Brook Trout	*Salvelinus fantinalis*	$Al_2(SO_4)_3$	35.4	% mortality at 300 ug/L Al	total?	30 d	0-30 d old	5.5	256-268	12	?	Cleveland et al. 1986	test duration not appropriate
Brook Trout	*Salvelinus fantinalis*	$Al_2(SO_4)_3$	44.9	% mortality at 300 ug/L Al	total?	15 d	0-30 d old	4.5	256-268	12	?	Cleveland et al. 1986	control failure, test duration not appropriate
Brook Trout	*Salvelinus fantinalis*	$Al_2(SO_4)_3$	53.2	% mortality at 300 ug/L Al	total?	30 d	0-30 d old	4.5	256-268	12	?	Cleveland et al. 1986	control failure, test duration not appropriate
Brook Trout	*Salvelinus fantinalis*	$Al_2(SO_4)_3$	1.3	% mortality at 300 ug/L Al	total?	15 d	37-67 d old	7.2	256-268	12	?	Cleveland et al. 1986	test duration not appropriate
Brook Trout	*Salvelinus fantinalis*	$Al_2(SO_4)_3$	1.3	% mortality at 300 ug/L Al	total?	30 d	37-67 d old	7.2	256-268	12	?	Cleveland et al. 1986	test duration not appropriate
Brook Trout	*Salvelinus fantinalis*	$Al_2(SO_4)_3$	32	% mortality at 300 ug/L Al	total?	15 d	37-67 d old	5.5	256-268	12	?	Cleveland et al. 1986	test duration not appropriate
Brook Trout	*Salvelinus fantinalis*	$Al_2(SO_4)_3$	39.7	% mortality at 300 ug/L Al	total?	30 d	37-67 d old	5.5	256-268	12	?	Cleveland et al. 1986	test duration not appropriate
Brook Trout	*Salvelinus fantinalis*	$Al_2(SO_4)_3$	22.5	% mortality at 300 ug/L Al	total?	15 d	37-67 d old	4.5	256-268	12	?	Cleveland et al. 1986	test duration not appropriate
Brook Trout	*Salvelinus fantinalis*	$Al_2(SO_4)_3$	32.1	% mortality at 300 ug/L Al	total?	30 d	37-67 d old	4.5	256-268	12	?	Cleveland et al. 1986	test duration not appropriate
Brook Trout	*Salvelinus fantinalis*	?	73	% mortality at 207 ug/L Al	total?	56 d	30 d old	5.3	soft	12	?	Cleveland et al. 1991	fish had avg 0.68 ug/g Al in body tissue from culture water
Brook Trout	*Salvelinus fantinalis*	?	48	% mortality at 217 ug/L Al	total?	56 d	30 d old	6.1	soft	12	?	Cleveland et al. 1991	fish had avg 0.68 ug/g Al in body tissue from culture water
Brook Trout	*Salvelinus fantinalis*	?	1.0	% mortality at 267 ug/L Al	total?	56 d	30 d old	7.2	soft	12	?	Cleveland et al. 1991	fish had avg 0.68 ug/g Al in body tissue from culture water
Brook Trout	*Salvelinus fantinalis*	naturally occurring	95	% survival at 41 ug/L Al	diss	39 d	sac fry	5.87	?	5-14	?	Fiss 1993	in situ test, controls? Test temp variation
Brook Trout	*Salvelinus fantinalis*	naturally occurring	86	% survival at 121 ug/L Al	diss	39 d	sac fry	4.98	?	5-14	?	Fiss 1993	in situ test, controls? Test temp variation
Brook Trout	*Salvelinus fantinalis*	naturally occurring	51	% survival at 202 ug/L Al	diss	39 d	sac fry	5.09	?	5-14	?	Fiss 1993	in situ test, controls? Test temp variation
Brook Trout	*Salvelinus fantinalis*	?	98	% survival at 20 ug/L Al	total	14 d	fry	5.2	soft	9-17	?	Driscoll et al. 1980	controls? Source of test organisms, test chemical?
Brook Trout	*Salvelinus fantinalis*	?	28	% survival at 420 ug/L Al	total	14 d	fry	5.2	soft	9-17	?	Driscoll et al. 1980	controls? Source of test organisms, test chemical?
Brook Trout	*Salvelinus fantinalis*	?	95	% survival at 10 ug/L Al	total	14 d	fry	4.4	soft	9-17	?	Driscoll et al. 1980	controls? Source of test organisms, test chemical?
Brook Trout	*Salvelinus fantinalis*	?	42	% survival at 480 ug/L Al	total	14 d	fry	4.4	soft	9-17	?	Driscoll et al. 1980	controls? Source of test organisms, test chemical?
Brook Trout	*Salvelinus fantinalis*	Al wire	90	% survival at 250 ug/L Al	total?	14 d	fry	4.9	?	9-11	?	Schofield 1980	
Brook Trout	*Salvelinus fantinalis*	Al wire	95	% survival at 100 ug/L Al	total?	14 d	fry	5.2	?	9-11	?	Schofield 1980	
Brook Trout	*Salvelinus fantinalis*	Al wire	63	% survival at 250 ug/L Al	total?	14 d	fry	5.2	?	9-11	?	Schofield 1980	
Brook Trout	*Salvelinus fantinalis*	$AlCl_3$	93.8	% survival at 172 ug/L Al	mono	193 d	18 mon old	4.8	soft	10.8	?	Mount et al. 1988 (2)	Ca = 7.4 mg/L
Brook Trout	*Salvelinus fantinalis*	$AlCl_3$	56.2	% survival at 169 ug/L Al	mono	193 d	18 mon old	4.8	soft	10.8	?	Mount et al. 1988 (2)	Ca =0.5 mg/L
Lake Trout	*Salvelinus namaycush*	naturally occurring	96.0	% survival at 163 ug/L Al	total	30 d	fry	6.3	?	4-10	?	Gunn 1984	in situ test using naturally occurring Al.
Lake Trout	*Salvelinus namaycush*	naturally occurring	93.7	% survival at 60 ug/L Al	total	59 d	fry	7.6	?	?	?	Gunn 1984	in situ test using naturally occurring Al.

ATTACHMENT 3. ALUMINUM TOXICITY DATA NOT USED IN CRITERIA CALCULATIONS
These studies have endpoints other than LC50, EC50 or TLm

Common Name	Genus species	Form of Aluminum Tested	Toxicity Value	Endpoint (units and Al concentration)	Tox value Total or Dissolved	Duration	Life stage	Test Conditions pH (s.u.)	Hardness (mg/l)	Temp (deg C)	TOC (mg/L)	Reference	Comments
Lake Trout	*Salvelinus namaycush*	naturally occurring	90.9	% survival at 60 ug/L Al	total	59 d	fry	7.6	?	?	?	Gunn 1984	In situ test using naturally occurring Al.
Rainbow Trout	*Oncorhynchus mykiss*	naturally occurring	97.9	% survival at 45 ug/L Al	total	59 d	fry	7.1	?	?	?	Gunn 1984	In situ test using naturally occurring Al.
Rainbow Trout	*Oncorhynchus mykiss*	$AlCl_3$	17.5	hrs to 50% mortality (LT50) at 162 ug/L Al	total?	40 d	juvenile	5.2	soft	15	?	Wilson et al. 1994	
Brown trout	*Salmo trutta*	$AlCl_3$	60	% mortality at 184 mg/L Al	total	48 hr	6-10 months	4.6	?	16	?	Witters et al 1996	
Brown Trout	*Salmo truta*	$AlCl_3$	98	% mortality at 184 mg/L Al	total	48 hr	juvenile	6.7, 4.6	?	16	?	Witters, et al. 1996	fish age not uniform, fish were not fed 7d or during testing
Brown trout	*Salmo trutta*	$Al(NO_3)_3$	500	time (hrs) to 50% mortality (LT50) at 477 ug/L Al	total	11-42 d	?	5.0	?	4.5	?	Poleo et al. 1997	controls contained Al, age of test organisms?
Cutthroat trout	*Oncorhynchus clarki*	$Al_2(SO_4)_3$	41	% survival at 50 ug/L Al	total	7 d	alevins	6.0	?	10	?	Woodward et al. 1989	dilution water = spring water + DI
Cutthroat trout	*Oncorhynchus clarki*	$Al_2(SO_4)_3$	94	% survival at 50 ug/L Al	total	7 d	alevins	5.5	?	10	?	Woodward et al. 1989	dilution water = spring water + DI
Cutthroat trout	*Oncorhynchus clarki*	$Al_2(SO_4)_3$	31	% survival at 100 ug/L Al	total	7 d	alevins	5.5	?	10	?	Woodward et al. 1989	dilution water = spring water + DI
Cutthroat trout	*Oncorhynchus clarki*	$Al_2(SO_4)_3$	71	% survival at 50 ug/L Al	total	7 d	alevins	5.0	?	10	?	Woodward et al. 1989	dilution water = spring water + DI
Cutthroat trout	*Oncorhynchus clarki*	$Al_2(SO_4)_3$	0	% survival at 100 ug/L Al	total	7 d	alevins	5.0	?	10	?	Woodward et al. 1989	dilution water = spring water + DI
Cutthroat trout	*Oncorhynchus clarki*	$Al_2(SO_4)_3$	0	% survival at 300 ug/L Al	total	7 d	alevins	5.0	?	10	?	Woodward et al. 1989	dilution water = spring water + DI
Cutthroat trout	*Oncorhynchus clarki*	$Al_2(SO_4)_3$	0	% survival at 300 ug/L Al	total	7 d	alevins	4.5	?	10	?	Woodward et al. 1989	dilution water = spring water + DI, control failure
Carp	*Cyprinus carpio*	$AlCl_3$	0	% mrotality at 2000 ug/L Al	total?	48 hr	?	6.6	?	16.5	?	Muramoto 1981	not enough test info given
Carp	*Cyprinus carpio*	$AlCl_3$	20	% mortality at 4000 ug/L Al	total?	48 hr	?	6.5	?	16.5	?	Muramoto 1981	not enough test info given
Carp	*Cyprinus carpio*	$AlCl_3$	20	% mortality at 8000 ug/L Al	total?	48 hr	?	6.3	?	16.5	?	Muramoto 1981	not enough test info given
Carp	*Cyprinus carpio*	$Al_2(SO_4)_3$	0	% mrotality at 2000 ug/L Al	total?	48 hr	?	6.6	?	16.5	?	Muramoto 1981	not enough test info given
Carp	*Cyprinus carpio*	$Al_2(SO_4)_3$	10	% mortality at 4000 ug/L Al	total?	48 hr	?	6.5	?	16.5	?	Muramoto 1981	not enough test info given
Carp	*Cyprinus carpio*	$Al_2(SO_4)_3$	10	% mortality at 8000 ug/L Al	total?	48 hr	?	6.3	?	16.5	?	Muramoto 1981	not enough test info given
Goldfish	*not noted in paper*	$Al_2(SO_4)_3$	0	% mortality at 50,000 ug/L Al	total?	7 d	?	6.6	?	?	?	Sanborn 1945	not enough test info given
Largemouth bass	*Micropterus salmoides*	$Al_2(SO_4)_3$	0	% mortality at 50,000 ug/L Al	total?	7 d	?	6.6	?	?	?	Sanborn 1945	not enough test info given
Blueback herring	*Alosa aestivalis*	$AlCl_3$	2	% mortality at 400 ug/L Al	total?	72 hr	embryos	6.5	23	20	?	Klauda et al 1987	
Blueback herring	*Alosa aestivalis*	$AlCl_3$	19	% mortality at 400 ug/L Al	total?	72 hr	embryos	7.8	23	20	?	Klauda et al 1987	
Atlantic salmon	*Salmo salar*	$AlCl_3$	106	time (hrs) to 50% mortality (LT50) at 75 ug/L Al	total?	20 d	smolt	5.06	?	?	?	Skogheim et al. 1986	in situ test Ca = 1.3 mg/L
Atlantic salmon	*Salmo salar*	$AlCl_3$	36	time (hrs) to 50% mortality (LT50) at 137 ug/L Al	total?	20 d	smolt	5.06	?	?	?	Skogheim et al. 1986	in situ test Ca = 1.3 mg/L
Atlantic salmon	*Salmo salar*	$Al(NO_3)_3$	85	time (hrs) to 50% mortality (LT50) at 381 ug/L Al	total	11-42 d	?	5.2	?	9.2	?	Poleo et al. 1997	controls contained Al, age of test organisms?
Perch	*Perca fluviatilis*	$Al(NO_3)_3$	360	time (hrs) to 50% mortality (LT50) at 492 ug/L Al	total	11-42 d	?	5.1	?	5.5	?	Poleo et al. 1997	controls contained Al, age of test organisms?
Grayling	*Thymallus thymallus*	$Al(NO_3)_3$	410	time (hrs) to 50% mortality (LT50) at 477 ug/L Al	total	11-42 d	?	5	?	4.5	?	Poleo et al. 1997	controls contained Al, age of test organisms?
Roach	*Rutilus rutilus*	$Al(NO_3)_3$	284	time (hrs) to 50% mortality (LT50) at 492 ug/L Al	total	11-42 d	?	5.1	?	6	?	Poleo et al. 1997	controls contained Al, age of test organisms?
Jefferson salamander	*Ambystoma jeffersonianum*	$AlCl_3$	16.7	% survival at 525 ug/L Al	total?	28 d	4 dph	4.5	low	ambient	?	Horne 1995	controls?
Jefferson salamander	*Ambystoma jeffersonianum*	$AlCl_3$	41.7	% survival at 525 ug/L Al	total?	28 d	4 dph	5.5	high	ambient	?	Horne 1995	controls?
Jefferson salamander	*Ambystoma jeffersonianum*	$AlCl_3$	75	% survival at 525 ug/L Al	total?	7 d	4 dph	4.5	low	ambient	?	Horne 1995	controls?
Jefferson salamander	*Ambystoma jeffersonianum*	$AlCl_3$	83.3	% survival at 525 ug/L Al	total?	7 d	4 dph	5.5	high	ambient	?	Horne 1995	controls?
Wood frog	*Rana sylvatica*	$AlCl_3$	0	% survival at 525 ug/L Al	total?	28 d	4 dph	4.5	low	ambient	?	Horne 1995	controls?
Wood frog	*Rana sylvatica*	$AlCl_3$	16.7	% survival at 525 ug/L Al	total?	28 d	4 dph	5.5	high	ambient	?	Horne 1995	controls?
Wood frog	*Rana sylvatica*	$AlCl_3$	75	% survival at 525 ug/L Al	total?	7 d	4 dph	4.5	low	ambient	?	Horne 1995	controls?
Wood frog	*Rana sylvatica*	$AlCl_3$	45.8	% survival at 525 ug/L Al	total?	7 d	4 dph	5.5	high	ambient	?	Horne 1995	controls?
Snail	*Lymnaea stagnalis*	$Al(NO_3)_3$	13	% mortality at 285 ug/L Al	total?	30 d	adults	7	?	10	?	Elangovan et al. 1996	
Planarian	*Polycelis nigra*	$Al(NO_3)_3$	110,000	ug/L Al threshold concentration	total?	48 hr	?	4.2	?	15-18	?	Jones 1940	
Duckweed	*Lemna minor*	$AlCl_3$	> 45,700	ug/L Al reduced frond production	?	4 d	?	7.6	?	24	?	Call 1984	not enough test information
Duckweed	*Lemna minor*	$AlCl_3$	> 45,700	ug/L Al reduced frond production	?	4 d	?	8.2	?	24	?	Call 1984	not enough test information

Note:
? = Information not found in original paper
dph = days post hatch

ATTACHMENT

B

DIVISION OF NATURAL RESOURCES
Wildlife Resources Section
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Joe Manchin III
Governor

Frank Jezioro
Director

October 31, 2005

Ms Jennie Henthorn
Bowles Rice McDavid Graff & Love LLP
600 Quarrier Street
Charleston, WV 25301

RE: Aluminum Aquatic Life Criteria Evaluation-Phase II

Ms Henthorn,

Thank you for the opportunity to review the referenced report. It is my opinion that ADVENT-ENVIRON adequately addressed the components of the "scope of work". I am providing my comments to you in accordance with your emailed instructions that accompanied the report, dated October 14, 2005.

On page 1, 2nd paragraph, I suggest that the acronym "TRINET" be defined.

On page 4, 2nd paragraph, ADVENT-ENVIRON stated that they considered potentially acceptable data, unacceptable if the toxicity test data were generated at a pH condition outside of 6-9. Because of the somewhat unusual dissolution curve of certain Al species related to pH and temperature, I believe that data outside of the 6-9 range may be useful and should be included for consideration by the body that will ultimately form the final aluminum standard rule. A pH below 6 is not uncommon in West Virginia waters and because of the potential for precipitated aluminum to negatively impact aquatic habitats; and the potential of pH increasing downstream of a low pH condition, I suggest that those studies be included if the only disqualifying feature is pH. Whatever final water quality standard for aluminum is promulgated, it will need to address not only the biological integrity (toxicity), but also the physical and chemical integrity of the waters of state.

Thank you again for the opportunity to review the referenced report. If you have any questions regarding my comments feel free to call or email me.

Best regards,

Kerry Bledsoe, Fishery Biologist
Wildlife Resources Section

ATTACHMENT

C

TITLE 47
LEGISLATIVE RULES
DEPARTMENT OF ENVIRONMENTAL PROTECTION

SERIES 2
REQUIREMENTS GOVERNING WATER QUALITY STANDARDS

§47-2-1. General.

1.1. Scope. -- These rules establish requirements governing the discharge or deposit of sewage, industrial wastes and other wastes into the waters of the state and establish water quality standards for the waters of the State standing or flowing over the surface of the State. It is declared to be the public policy of the State of West Virginia to maintain reasonable standards of purity and quality of the water of the State consistent with (1) public health and public enjoyment thereof; (2) the propagation and protection of animal, bird, fish, and other aquatic and plant life; and (3) the expansion of employment opportunities, maintenance and expansion of agriculture and the provision of a permanent foundation for healthy industrial development. (See W. Va. Code §22-11-2.)

1.2. Authority. -- W. Va. Code §22-11-4(a)(16); §22-11-7b

1.3. Filing Date. -- April 11, 2008.

1.4. Effective Date. -- July 1, 2008.

§47-2-2. Definitions.

The following definitions in addition to those set forth in W. Va. Code §22-11-3, shall apply to these rules unless otherwise specified herein, or unless the context in which used clearly requires a different meaning:

2.1. "Conventional treatment" is the treatment of water as approved by the West Virginia Bureau for Public Health to assure that the water is safe for human consumption.

2.2. "Cool water lakes" are lakes managed by the West Virginia Division of Natural Resources for cool water fisheries, with summer residence times greater than 14 days.

2.3. "Cumulative" means a pollutant which increases in concentration in an organism by successive additions at different times or in different ways (bio-accumulation).

2.4. "Designated uses" are those uses specified in water quality standards for each water or segment whether or not they are being attained. (See sections 6.2 - 6.6, herein)

2.5. "Dissolved metal" is operationally defined as that portion of metal which passes through a 0.45 micron filter.

2.6. "Existing uses" are those uses actually attained in a water on or after November 28, 1975, whether or not they are included in the water quality standards.

2.7. The "Federal Act" means the Clean Water Act (also known as the Federal Water Pollution Control Act) 33 U.S.C. § 1251 - 1387.

2.8. "High quality waters" are those waters whose quality is equal to or better than the minimum levels necessary to achieve the national water quality goal uses.

2.9. "Intermittent streams" are streams which have no flow during sustained periods of no precipitation and which do not support aquatic life whose life history requires residence in flowing waters for a continuous period of at least six (6) months.

2.10. "Outstanding national resource waters" are those waters whose unique character, ecological or recreational value or pristine nature constitutes a valuable national or State resource.

2.11. "Natural" or "naturally occurring" values or "natural temperature" shall mean for all of the waters of the state:

2.11.a. Those water quality values which exist unaffected by -- or unaffected as a consequence of -- any water use by any person; and

2.11.b. Those water quality values which exist unaffected by the discharge, or direct or indirect deposit of, any solid, liquid or gaseous substance from any point source or non-point source.

2.12. "Non-point source" shall mean any source other than a point source from which pollutants may reach the waters of the state.

2.13. "Persistent" shall mean a pollutant and its transformation products which under natural conditions degrade slowly in an aquatic environment.

2.14. "Point source" shall mean any discernible, confined and discrete conveyance, including, but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural stormwater discharges and return flows from irrigated agriculture.

2.15. "Representative important species of aquatic life" shall mean those species of aquatic life whose protection and propagation will assure the sustained presence of a balanced aquatic community. Such species are representative in the sense that maintenance of water quality criteria will assure both the natural completion of the species' life cycles and the overall protection and sustained propagation of the balanced aquatic community.

2.16. "Secretary" shall mean the Secretary of the Department of Environmental Protection or such other person to whom the Secretary has delegated authority or duties pursuant to W. Va. Code §§22-1-6 or 22-1-8.

2.17. The "State Act" or "State Law" shall mean the West Virginia Water Pollution Control Act, W. Va. Code §22-11-1 et seq.

2.18. "Total recoverable" refers to the digestion procedure for certain heavy metals as referenced in 40 CFR 136, as amended June 15, 1990 and March 26, 2007, Guidelines Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act.

2.19. "Trout waters" are waters which sustain year-round trout populations. Excluded are those waters which receive annual stockings of trout but which do not support year-round trout populations.

2.20. "Water quality criteria" shall mean levels of parameters or stream conditions that are required to be maintained by these regulations. Criteria may be expressed as a constituent concentration, levels, or narrative statement, representing a quality of water that supports a designated use or uses.

2.21. "Water quality standards" means the combination of water uses to be protected and the water quality criteria to be maintained by these rules.

2.22. "Wetlands" are those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas.

2.23. "Wet weather streams" are streams that flow only in direct response to precipitation or whose channels are at all times above the water table.

§47-2-3. Conditions Not Allowable In State Waters.

3.1. Certain characteristics of sewage, industrial wastes and other wastes cause pollution and are objectionable in all waters of the state. Therefore, the Secretary does hereby proclaim that the following general conditions are not to be allowed in any of the waters of the state.

3.2. No sewage, industrial wastes or other wastes present in any of the waters of the state shall cause therein or materially contribute to any of the following conditions thereof:

3.2.a. Distinctly visible floating or settleable solids, suspended solids, scum, foam or oily slicks;

3.2.b. Deposits or sludge banks on the bottom;

3.2.c. Odors in the vicinity of the waters;

3.2.d. Taste or odor that would adversely affect the designated uses of the affected waters;

3.2.e. Materials in concentrations which are harmful, hazardous or toxic to man, animal or aquatic life;

3.2.f. Distinctly visible color;

3.2.g. Concentrations of bacteria which may impair or interfere with the designated uses of the affected waters;

3.2.h. Requiring an unreasonable degree of treatment for the production of potable water by modern water treatment processes as commonly employed; and

3.2.i. Any other condition, including radiological exposure, which adversely alters the integrity of the waters of the State including wetlands; no significant adverse impact to the chemical, physical, hydrologic, or biological components of aquatic ecosystems shall be allowed.

§47-2-4. Antidegradation Policy.

4.1. It is the policy of the State of West Virginia that the waters of the state shall be maintained and protected as follows:

4.1.a. Tier 1 Protection. Existing water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected. Existing uses are those uses actually attained in a water on or after November 28, 1975, whether or not they are included as designated uses within these water quality standards.

4.1.b. Tier 2 Protection. The existing high quality waters of the state must be maintained at their existing high quality unless it is determined after satisfaction of the intergovernmental coordination of the state's continuing planning process and opportunity for public comment and hearing that allowing lower water quality is necessary to accommodate important economic or social development in the area in which the waters are located. If limited degradation is allowed, it shall not result in injury or interference with existing stream water uses or in violation of state or federal water quality criteria that describe the base levels necessary to sustain the national water quality goal uses of protection and propagation of fish, shellfish and wildlife and recreating in and on the water.

In addition, the Secretary shall assure that all new and existing point sources shall achieve the highest established statutory and regulatory requirements applicable to them and shall assure the achievement of cost-effective and reasonable best management practices (BMPs) for non-point source control. If BMPs are demonstrated to be inadequate to reduce or minimize water quality impacts, the Secretary may require that more appropriate BMPs be developed and applied.

4.1.b.1. High quality waters are those waters meeting the definition at section 2.8 herein.

4.1.b.2. High quality waters may include but are not limited to the following:

4.1.b.2.A. Streams designated by the West Virginia Legislature under the West Virginia Natural Stream Preservation Act, pursuant to W. Va. Code §22-13-5; and

4.1.b.2.B. Streams listed in West Virginia High Quality Streams, Fifth Edition, prepared by the Wildlife Resources Division, Department of Natural Resources (1986).

4.1.b.2.C. Streams or stream segments which receive annual stockings of trout but which do not support year-round trout populations.

4.1.c. Tier 3 Protection. In all cases, waters which constitute an outstanding national resource shall be maintained and protected and improved where necessary. Outstanding national resource waters include, but are not limited to, all streams and rivers within the boundaries of Wilderness Areas designated by The Wilderness Act (16 U.S.C. §1131 et seq.) within the State, all Federally designated rivers under the "Wild and Scenic Rivers Act", 16 U.S.C. §1271 et seq.; all streams and other bodies of water in state parks which are high quality waters or naturally reproducing trout streams; waters in national parks and forests which are high quality waters or naturally reproducing tout streams; waters designated under the "National Parks and Recreation Act of 1978", as amended; and pursuant to subsection 7.1 of 60CSR5, those waters whose unique character, ecological or recreational value, or pristine nature constitutes a valuable national or state resource.

Additional waters may be nominated for inclusion in that category by any interested party or by the Secretary on his or her own initiative. To designate a nominated water as an outstanding national resource water, the Secretary shall follow the public notice and hearing provisions as provided in 46 C.S.R. 6.

4.1.d. All applicable requirements of section 316(a) of the Federal Act shall apply to modifications of the temperature water quality criteria provided for in these rules.

§47-2-5. Mixing Zones.

5.1. In the permit review and planning process or upon the request of a permit applicant or permittee, the Secretary may establish on a case-by-case basis an appropriate mixing zone.

5.2. The following guidelines and conditions are applicable to all mixing zones:

5.2.a. The Secretary will assign, on a case-by-case basis, definable geometric limits for mixing zones for a discharge or a pollutant or pollutants within a discharge. Applicable limits shall include, but may not be limited to, the linear distances from the point of discharge, surface area involvement, volume of receiving water, and shall take into account other nearby mixing zones. Mixing zones shall take into account the mixing conditions in the receiving stream (i.e: whether complete or incomplete mixing conditions exist). Mixing zones will not be allowed until applicable limits are assigned by the Secretary in accordance with this section.

5.2.b. Concentrations of pollutants which exceed the acute criteria for protection of aquatic life set forth in Appendix E, Table 1 shall not exist at any point within an assigned mixing zone or in the discharge itself unless a zone of initial dilution is assigned. A zone of initial dilution may be assigned on a case-by-case basis at the discretion of the Secretary. The zone of initial dilution is the area within the mixing zone where initial dilution of the effluent with the receiving water occurs, and where the concentration of the effluent will be its greatest in the water column. Where a zone of initial dilution is assigned by the Secretary, the size of the zone shall be determined using one of the four alternatives outlined in section 4.3.3 of US EPA's Technical Support Document for Water Quality-based Toxics Control (EPA/505/2-90-001 PB91-127415, March 1991). Concentrations of pollutants shall not exceed the acute criteria at the edge of the assigned zone of initial dilution. Chronic criteria for the protection of aquatic life may be exceeded within the mixing zone but shall be met at the edge of the assigned mixing zone.

5.2.c. Concentrations of pollutants which exceed the criteria for the protection of human health set forth in Appendix E, Table 1 shall not be allowed at any point unless a mixing zone has been assigned by the Secretary after consultation with the Commissioner of the West Virginia Bureau for Public Health. Human health criteria may be exceeded within an assigned mixing zone, but shall be met at the edge of the assigned mixing zone. Mixing zones for human health criteria shall be sized to prevent significant human health risks and shall be developed using reasonable assumptions about exposure pathways. In assessing the potential human health risks of establishing a mixing zone upstream from a drinking water intake, the Secretary shall consider the cumulative effects of multiple discharges and mixing zones on the drinking water intake. No mixing zone for human health criteria shall be established on a stream which has a seven (7) day, ten (10) year return frequency of 5 cfs or less.

5.2.d. Mixing zones, including zones of initial dilution, shall not interfere with fish spawning or nursery areas or fish migration routes; shall not overlap public water supply intakes or bathing areas; cause lethality to or preclude the free passage of fish or other aquatic life; nor harm any threatened or endangered species, as listed in the Federal Endangered Species Act, 15 U.S.C. §1531 et seq.

5.2.e. The mixing zone shall not exceed one-third (1/3) of the width of the receiving stream, and in no case shall the mixing zone exceed one-half (1/2) of the cross-sectional area of the receiving stream.

5.2.f. In lakes and other surface impoundments, the volume of a mixing zone shall not affect in excess of ten (10) percent of the volume of that portion of the receiving waters available for mixing.

5.2.g. A mixing zone shall be limited to an area or volume which will not adversely alter the existing or designated uses of the receiving water, nor be so large as to adversely affect the integrity of the water.

5.2.h. Mixing zones shall not:

5.2.h.1. Be used for, or considered as, a substitute for technology-based requirements of the Act and other applicable state and federal laws.

5.2.h.2. Extend downstream at any time a distance more than five times the width of the receiving watercourse at the point of discharge.

5.2.h.3. Cause or contribute to any of the conditions prohibited in section 3, herein.

5.2.h.4. Be granted where instream waste concentration of a discharge is greater than 80%.

5.2.h.5. Overlap one another.

5.2.h.6. Overlap any 1/2 mile zone described in section 7.2.a.2 herein.

5.2.i. In the case of thermal discharges, a successful demonstration conducted under section 316(a) of the Act shall constitute compliance with all provisions of this section.

5.2.j. The Secretary may waive the requirements of subsections 5.2.e and 5.2.h.2 above if a discharger provides an acceptable demonstration of:

5.2.j.1. Information defining the actual boundaries of the mixing zone in question; and

5.2.j.2. Information and data proving no violation of subsections 5.2.d and 5.2.g above by the mixing zone in question.

5.2.k. Upon implementation of a mixing zone in a permit, the permittee shall provide documentation that demonstrates to the satisfaction of the Secretary that the mixing zone is in compliance with the provisions outlined in subsections 5.2.b, 5.2.c, 5.2.e, and 5.2.h.2, herein.

5.2.l. In order to facilitate a determination or assessment of a mixing zone pursuant to this section, the Secretary may require a permit applicant or permittee to submit such information as deemed necessary.

§47-2-6. Water Use Categories.

6.1. These rules establish general Water Use Categories and Water Quality Standards for the waters of the State. Unless otherwise designated by these rules, at a minimum all waters of the State are designated for the Propagation and Maintenance of Fish and Other Aquatic Life (Category B) and for Water Contact Recreation (Category C) consistent with Federal Act goals. Incidental utilization for whatever purpose may or may not constitute a justification for assignment of a water use category to a particular stream segment.

6.1.a. Waste assimilation and transport are not recognized as designated uses. The classification of the waters must take into consideration the use and value of water for public water supplies, protection and propagation of fish, shellfish and wildlife, recreation in and on the water, agricultural, industrial and other purposes including navigation.

Subcategories of a use may be adopted

and appropriate criteria set to reflect varying needs of such subcategories of uses, for example to differentiate between trout water and other waters.

6.1.b. At a minimum, uses are deemed attainable if they can be achieved by the imposition of effluent limits required under section 301(b) and section 306 of the Federal Act and use of cost-effective and reasonable best management practices for non-point source control. Seasonal uses may be adopted as an alternative to reclassifying a water or segment thereof to uses requiring less stringent water quality criteria. If seasonal uses are adopted, water quality criteria will be adjusted to reflect the seasonal uses; however, such criteria shall not preclude the attainment and maintenance of a more protective use in another season. A designated use which is not an existing use may be removed, or subcategories of a use may be established if it can be demonstrated that attaining the designated use is not feasible because:

6.1.b.1. Application of effluent limitations for existing sources more stringent than those required pursuant to section 301 (b) and section 306 of the Federal Act in order to attain the existing designated use would result in substantial and widespread adverse economic and social impact; or

6.1.b.2. Naturally-occurring pollutant concentrations prevent the attainment of the use; or

6.1.b.3. Natural, ephemeral, intermittent or low flow conditions of water levels prevent the attainment of the use, unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges to enable uses to be met; or

6.1.b.4. Human-caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place; or

6.1.b.5. Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water to its original condition or to operate such modification in a way that would result in the attainment of the use; or

6.1.b.6. Physical conditions related to the natural features of the water, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses.

6.1.c. The State shall take into consideration the quality of downstream waters and shall assure that its water quality standards provide for the attainment of the water quality standards of downstream waters.

6.1.d. In establishing a less restrictive use or uses, or subcategory of use or uses, and the water quality criteria based upon such uses, the Secretary shall follow the requirements for revision of water quality standards as required by W. Va. Code §22-11-7b and section 303 of the Federal Act and the regulations thereunder. Any revision of water quality standards shall be made with the concurrence of EPA. The Secretary's administrative procedural regulations for applying for less restrictive uses or criteria shall be followed.

6.2. Category A -- Water Supply, Public. -- This category is used to describe waters which, after conventional treatment, are used for human consumption. This category includes streams on which the following are located:

6.2.a. All community domestic water supply systems;

6.2.b. All non-community domestic water supply systems, (i.e. hospitals, schools, etc.);

6.2.c. All private domestic water systems;

6.2.d. All other surface water intakes where the water is used for human consumption. (See Appendix B for partial listing of Category A waters; see section 7.2.a.2, herein for additional requirements for Category A waters.) The manganese human health criterion shall only apply within the five-mile zone immediately upstream above a known public or private water supply used for human consumption.

6.3. Category B -- Propagation and maintenance of fish and other aquatic life. --

This category includes:

6.3.a. Category B1 -- Warm water fishery streams. -- Streams or stream segments which contain populations composed of all warm water aquatic life.

6.3.b. Category B2 -- Trout Waters. -- As defined in section 2.19, herein (See Appendix A for a representative list.)

6.3.c. Category B4 -- Wetlands. -- As defined in section 2.22, herein; certain numeric stream criteria may not be appropriate for application to wetlands (see Appendix E, Table 1).

6.4. Category C -- Water contact recreation. -- This category includes swimming, fishing, water skiing and certain types of pleasure boating such as sailing in very small craft and outboard motor boats. (See Appendix D for a representative list of category C waters.)

6.5. Category D. -- Agriculture and wildlife uses.

6.5.a. Category D1 -- Irrigation. -- This category includes all stream segments used for irrigation.

6.5.b. Category D2 -- Livestock watering. -- This category includes all stream segments used for livestock watering.

6.5.c. Category D3 -- Wildlife. -- This category includes all stream segments and wetlands used by wildlife.

6.6. Category E -- Water supply industrial, water transport, cooling and power. -- This category includes cooling water, industrial water supply, power production, commercial and pleasure vessel activity, except those small craft included in Category C.

6.6.a. Category E1 -- Water Transport. -- This category includes all stream segments modified for water transport and having permanently maintained navigation aides.

6.6.b. Category E2 -- Cooling Water. -- This category includes all stream segments having one (1) or more users for industrial cooling.

6.6.c. Category E3 -- Power production. -- This category includes all stream segments extending from a point 500 feet upstream from the intake to a point one half (1/2) mile below the wastewater discharge point. (See Appendix C for representative list.)

6.6.d. Category E4 -- Industrial. -- This category is used to describe all stream segments with one (1) or more industrial users. It does not include water for cooling.

§47-2-7. West Virginia Waters.

7.1. Major River Basins and their Alphanumeric System. All streams and their tributaries in West Virginia shall be individually identified using an alphanumeric system as identified in the "Key to West Virginia Stream Systems and Major Tributaries" (1956) as published by the Conservation Commission of West Virginia and revised by the West Virginia Department of Natural Resources, Division of Wildlife (1985).

7.1.a. J - James River Basin. All tributaries to the West Virginia - Virginia State line.

7.1.b. P - Potomac River Basin. All tributaries of the main stem of the Potomac River to the West Virginia - Maryland - Virginia State line to the confluence of the North Branch and the South Branch of the Potomac River and all tributaries arising in West Virginia excluding the major tributaries hereinafter designated:

7.1.b.1. S - Shenandoah River and all its tributaries arising in West Virginia to the West Virginia - Virginia State line.

7.1.b.2. PC - Cacapon River and all its tributaries.

7.1.b.3. PSB - South Branch and all its tributaries.

7.1.b.4. PNB - North Branch and all tributaries to the North Branch arising in West Virginia.

7.1.c. M - Monongahela River Basin. The Monongahela River Basin main stem and all its tributaries excluding the following major tributaries which are designated as follows:

7.1.c.1. MC - Cheat River and all its tributaries except those listed below:

7.1.c.1.A. MCB - Blackwater River and all its tributaries.

7.1.c.2. MW - West Fork River and all its tributaries.

7.1.c.3. MT - Tygart River and all its tributaries except those listed below:

7.1.c.3.A. MTB - Buckhannon River and all its tributaries.

7.1.c.3.B. MTM - Middle Fork River and all its tributaries.

7.1.c.4. MY - Youghigheny River and all its tributaries to the West Virginia - Maryland State line.

7.1.d. O Zone 1 - Ohio River - Main Stem. The main stem of the Ohio River from the Ohio - Pennsylvania - West Virginia state line to the Ohio - Kentucky - West Virginia State line.

7.1.e. O Zone 2 - Ohio River - Tributaries. All tributaries of the Ohio River excluding the following major tributaries:

7.1.e.1. LK - Little Kanawha River. The Little Kanawha River and all its tributaries excluding the following major tributary which is designated as follows:

7.1.e.1.A. LKH - Hughes River and all its tributaries.

7.1.e.2. K - Kanawha River Zone 1. The main stem of the Kanawha River from mile point 0, at its confluence with the Ohio River, to mile point 72 near Diamond, West Virginia.

7.1.e.3. K - Kanawha River Zone 2. The main stem of the Kanawha River from mile point 72 near Diamond, West Virginia and all its tributaries from mile point 0 to the headwaters excluding the following major tributaries which are designated as follows:

7.1.e.3.A. KP - Pocatalico River and all its tributaries.

7.1.e.3.B. KC - Coal River and all its tributaries.

7.1.e.3.C. KE - Elk River and all its tributaries.

7.1.e.3.D. KG - Gauley River. The Gauley River and all its tributaries excluding the following major tributaries which are designated as follows:

7.1.e.3.D.1. KG-19 - Meadow River and all its tributaries.

7.1.e.3.D.2. KG-34 - Cherry River and all its tributaries.

7.1.e.3.D.3. KGC - Cranberry River and all its tributaries.

7.1.e.3.D.4. KGW - Williams River and all its tributaries.

7.1.e.3.E. KN - New River. The New River from its confluence with the Gauley River to the Virginia - West Virginia State line and all tributaries excluding the following major tributaries which are designated as follows:

7.1.e.3.E.1. KNG - Greenbrier River and all its tributaries.

7.1.e.3.E.2. KNB - Bluestone River and all its tributaries.

7.1.e.3.E.3. KN-60 - East River and all its tributaries.

7.1.e.3.E.4. K(L)-81-(1) - Bluestone Lake.

7.1.e.4. OG - Guyandotte River.

The Guyandotte River and all its tributaries excluding the following major tributary which is designated as follows:

7.1.e.4.1. OGM - Mud River and all its tributaries.

7.1.e.5. BS - Big Sandy River. The Big Sandy River to the Kentucky - Virginia - West Virginia State lines and all its tributaries arising in West Virginia excluding the following major tributary which is designated as follows:

7.1.e.5.1 BST - Tug Fork and all its tributaries.

7.2. Applicability of Water Quality Standards. The following shall apply at all times unless a specific exception is granted in this section:

7.2.a. Water Use Categories as described in section 6, herein.

7.2.a.1. Based on meeting those Section 6 definitions, tributaries or stream segments may be classified for one or more Water Use Categories. When more than one use exists, they shall be protected by criteria for the use category requiring the most stringent protection.

7.2.a.2. Each segment extending upstream from the intake of a water supply public (Water Use Category A), for a distance of one half (1/2) mile or to the headwater, must be protected by prohibiting the discharge of any pollutants in excess of the concentrations designated for this Water Use Category in section 8, herein. In addition, within that one half (1/2) mile zone, the Secretary may establish for any discharge, effluent limitations for the protection of human health that require additional removal of pollutants than would otherwise be provided by this rule. (If a watershed is not significantly larger than this zone above the intake, the water supply section may include the entire upstream watershed to its headwaters.) Until September 1, 2010, or until action by the Secretary to revise this provision, whichever comes first, the one-half (1/2) mile zone described in this section shall not apply to the Ohio River main channel (between Brown's Island and the left descending bank) between river mile points 61.0 and 63.5 for the Category A criterion for iron as set forth in §8 herein. Weirton Steel Corporation shall conduct monthly monitoring of the treated water at its drinking water plant for iron and submit the results of such monitoring to the West Virginia Bureau for Public Health and the Office of Water Resources of the West Virginia Department of Environmental Protection. In addition, Weirton Steel Corporation shall submit a written report regarding the status of its drinking water plant and the issues pertaining thereto to the Secretary on or before March 1, 2007.

7.2.b. In the absence of any special application or contrary provision, water quality standards shall apply at all times when flows are equal to or greater than the minimum mean seven (7) consecutive day drought flow with a ten (10) year return frequency (7Q10). NOTE: With the exception of section 7.2.c.5 listed herein exceptions do not apply to trout waters nor to the requirements of section 3, herein.

7.2.c. Exceptions: Numeric water quality standards shall not apply: (See section 7.2.d, herein, for site-specific revisions)

7.2.c.1. When the flow is less than 7Q10;

7.2.c.2. In wet weather streams (or intermittent streams, when they are dry or have no measurable flow): Provided, that the existing and designated uses of downstream waters are not adversely affected;

7.2.c.3. In any assigned zone of initial dilution of any mixing zone where a zone of initial dilution is required by section 5.2.b herein, or in any assigned mixing zone for human health criteria or aquatic life criteria for which a zone of initial dilution is not assigned; In zones of initial dilution and certain mixing zones: Provided, That all requirements described in section 5 herein shall apply to all zones of initial dilution and all mixing zones;

7.2.c.4. Where, on the basis of natural conditions, the Secretary has established a site-specific aquatic life water quality criterion that modifies a water quality criterion set out in Appendix E, Table 1 of this rule. Where a natural condition of a water is demonstrated to be of lower quality than a water quality criterion for the use classes and subclasses in section 6 of this rule, the Secretary, in his or her discretion, may establish a site-specific water quality criterion for aquatic life. This alternate criterion may only serve as the chronic criterion established for that parameter. This alternate criterion must be met at end of pipe. Where the Secretary decides to establish a site-specific water quality criterion for aquatic life, the natural condition constitutes the applicable water quality criterion. A site-specific criterion for natural conditions may only be established through the legislative rulemaking process in accordance with W.Va. Code §29A-3-1 et seq. and must satisfy the public participation requirements set forth at 40 C.F.R. 131.20 and 40 C.F.R. Part 25. Site-specific criteria for natural conditions may be established only for aquatic life criteria. A public notice, hearing and comment period is required before site-specific criteria for natural conditions are established.

Upon application or on its own initiative, the Secretary will determine whether a natural condition of a water should be approved as a site-specific water quality criterion. Before he or she approves a site-specific water quality criterion for a natural condition, the Secretary must find that the natural condition will fully protect existing and designated uses and ensure the protection of aquatic life. If a natural condition of a water varies with time, the natural condition will be determined to be the actual natural condition of the water measured prior to or concurrent with discharge or operation. The Secretary will, in his or her discretion, determine a natural condition for one or more seasonal or shorter periods to reflect variable ambient conditions; and require additional or continuing monitoring of natural conditions.

An application for a site-specific criterion to be established on the basis of natural conditions shall be filed with the Secretary and shall include the following information:

7.2.c.4.A. A U.S.G.S. 7.5 minute map showing the stream segment affected and showing all existing discharge points and proposed discharge point;

7.2.c.4.B. The alphanumeric code of the affected stream, if known;

7.2.c.4.C. Water quality data for the stream or stream segment. Where adequate data are unavailable, additional studies may be required by the Secretary;

7.2.c.4.D. General land uses (e.g. mining, agricultural, recreation, residential, commercial, industrial, etc.) as well as specific land uses adjacent to the waters for the affected segment or stream;

7.2.c.4.E. The existing and designated uses of the receiving waters into which the segment in question discharges and the location where those downstream uses begin to occur;

7.2.c.4.F. General physical characteristics of the stream segment, including, but not limited to width, depth, bottom composition and slope;

7.2.c.4.G. Conclusive information and data of the source of the natural condition that causes the stream to exceed the water quality standard for the criterion at issue.

7.2.c.4.H. The average flow rate in the segment and the amount of flow at a designated control point and a statement regarding whether the flow of the stream is ephemeral, intermittent or perennial;

7.2.c.4.I. An assessment of aquatic life in the stream or stream segment in question and in the adjacent upstream and downstream segments; and

7.2.c.4.J. Any additional information or data that the Secretary deems necessary to make a decision on the application.

7.2.c.5. For the upper Blackwater River from the mouth of Yellow Creek to a point 5.1 miles upstream, when flow is less than 7Q10. Naturally occurring values for Dissolved Oxygen as established by data collected by the dischargers within this reach and reviewed by the Secretary shall be the applicable criteria.

7.2.d. Site-specific applicability of

water use categories and water quality criteria - State-wide water quality standards shall apply except where site-specific numeric criteria, variances or use removals have been approved following application and hearing, as provided in 46 C.S.R. 6. (See section 8.4 and section 8.5, herein) The following are approved site-specific criteria, variances and use reclassifications:

7.2.d.1. James River - (Reserved)

7.2.d.2. Potomac River

7.2.d.2.1. A site-specific numeric criterion for aluminum, not to exceed 500 ug/l, shall apply to the section of Opequon Creek from Turkey Run to the Potomac River.

7.2.d.3. Shenandoah River - (Reserved)

7.2.d.4. Cacapon River - (Reserved)

7.2.d.5. South Branch - (Reserved)

7.2.d.6. North Branch - (Reserved)

7.2.d.7. Monongahela River

7.2.d.7.1. Flow in the main stem of the Monongahela River, as regulated by the Tygart Reservoir, operated by the U. S. Army Corps of Engineers, is based on a minimum flow of 345 cfs at Lock and Dam No. 8, river mile point 90.8. This exception does not apply to tributaries of the Monongahela River.

7.2.d.8. Cheat River

7.2.d.8.1. In the unnamed tributary of Daugherty Run, approximately one mile upstream of Daugherty Run's confluence with the Cheat River, a site-specific numeric criterion for iron of 3.5 mg/l shall apply and the following frequency and duration requirements shall apply to the chronic numeric criterion for selenium (5ug/l): the four-day average concentration shall not be exceeded more than three times every three years (36 months), on average. Further, the following site-specific numeric criteria shall apply to Fly Ash Run of Daugherty Run: acute numeric criterion for aluminum: 888.5 ug/l and manganese: 5 mg/l.

7.2.d.9. Blackwater River - (Reserved)

7.2.d.10. West Fork River - (Reserved)

7.2.d.11. Tygart River - (Reserved)

7.2.d.12. Buckhannon River - (Reserved)

7.2.d.13. Middle Fork River - (Reserved)

7.2.d.14. Youghiogheny River - (Reserved)

7.2.d.15. Ohio River Main Stem - (Reserved)

7.2.d.16. Ohio River Tributaries.

7.2.d.16.1. Site-specific numeric criteria shall apply to the stretch of Conners Run (0-77-A), a tributary of Fish Creek, from its mouth to the discharge from Conner Run impoundment, which shall not have the Water Use Category A and may contain selenium not to exceed 62 ug/1; and iron not to exceed 3.5 mg/l as a monthly average and 7 mg/l as a daily maximum.

7.2.d.16.2. A socio-economic variance shall apply to that segment of Harmon Creek (0-97) from its confluence with the Ohio River to a point 2.2 miles upstream, which shall not have water use Category A designation, and which shall have the following instream criteria: Lead 14 ug/l, Daily Maximum, Temperature 100 degree F (monitored per Footnote 12 of the permit); Iron 4.0 mg/l, monthly average and 8.0 mg/l Daily Maximum (monitored per Footnote 12 of the permit). Weirton Steel Corporation shall continue to submit to the Secretary, on an annual basis summary reports on the water quality of the discharge from Outlet 004 and the efforts made by Weirton Steel Corporation during the previous year to improve the quality of the discharge. These exceptions shall be in effect until action by the Secretary to revise the exceptions or until July 1, 2009, whichever comes first.

7.2.d.17. Little Kanawha River - (Reserved)

7.2.d.18. Hughes River - (Reserved)

7.2.d.19. Kanawha River Zone 1 - Main Stem

7.2.d.19.1. For the Kanawha River main stem, Zone 1, Water Use Category A shall not apply; and

7.2.d.19.2. The minimum flow shall be 1,960 cfs at the Charleston gauge.

7.2.d.19.3. A variance pursuant to 46 CSR 6, Section 5.1, based on naturally occurring pollutant concentrations, shall apply to Union Carbide Corporation's discharge to Ward Hollow of Davis Creek, which shall have the instream criteria for chlorides of 310 mg/l for Category A and C waters and for Category B1 (chronic aquatic life protection). This exception shall be in effect until action by the Secretary to revise the exception or until July 1, 2010, whichever comes first.

7.2.d.20. Kanawha River Zone 2 and Tributaries.

7.2.d.20.1. For the main stem of the Kanawha River only, the minimum flow shall be 1,896 cfs at mile point 72.

7.2.d.20.2. The stretch between the mouth of Little Scary Creek (K-31) and the Little Scary impoundment shall not have Water Use Category A. The following site-specific numeric criteria shall apply to that section: selenium not to exceed 62 ug/l and copper not to exceed 105 ug/l as a daily maximum nor 49 ug/l as a 4-day average.

7.2.d.21. Pocatalico River - (Reserved)

7.2.d.22. Coal River - (Reserved)

7.2.d.23. Elk River - (Reserved)

7.2.d.24. Gauley River - (Reserved)

7.2.d.25. Meadow River - (Reserved)

7.2.d.26. Cherry River - (Reserved)

7.2.d.27. Cranberry River - (Reserved)

7.2.d.28. Williams River - (Reserved)

7.2.d.29. New River - (Reserved)

7.2.d.30. Greenbrier River - (Reserved)

7.2.d.31. Bluestone River - (Reserved)

7.2.d.32. Bluestone Lake - (Reserved)

7.2.d.33. East River - (Reserved)

7.2.d.34. Guyandotte River -

7.2.d.34.1. Pats Branch from its confluence with the Guyandotte River to a point 1000 feet upstream shall not have Water Use Category A and Category D1 designation.

7.2.d.35. Mud River - (Reserved)

7.2.d.36. Big Sandy River - (Reserved)

7.2.d.37. Tug Fork River - (Reserved)

§47-2-8. Specific Water Quality Criteria.

8.1. Charts of specific water quality criteria are included in Appendix E, Table 1.

8.1.a. Specific state (i.e. total, total recoverable, dissolved, valence, etc.) of any parameter to be analyzed shall follow 40 CFR 136, Guidelines Establishing Test Procedures for Analysis of Pollutants Under the Clean Water Act, as amended, June 15, 1990 and March 26, 2007. (See also 47 C.S.R. 10, section 7.3 - National Pollutant Discharge Elimination System (NPDES) Program.)

8.1.b. Compliance with aquatic life

water quality criteria expressed as dissolved metal shall be determined based on dissolved metals concentrations.

8.1.b.1. The aquatic life criteria for all metals listed in Appendix E, Table 2 shall be converted to a dissolved concentration by multiplying each numerical value or criterion equation from Appendix E, Table 1 by the appropriate conversion factor (CF) from Appendix E, Table 2.

8.1.b.2. Permit limits based on dissolved metal water quality criteria shall be prepared in accordance with the U.S. EPA document "The Metals Translator: Guidance For Calculating A Total Recoverable Permit Limit From A Dissolved Criterion, EPA 823-B-96-007 June 1996.

8.1.b.3. NPDES permit applicants may petition the Secretary to develop a site-specific translator consistent with the provisions in this section. The Secretary may, on a case-by-case basis require an applicant applying for a translator to conduct appropriate sediment monitoring through SEM/AVS ratio, bioassay or other approved methods to evaluate effluent limits that prevent toxicity to aquatic life.

8.1.c. An "X" or numerical value in the use columns of Appendix E, Table 1 shall represent the applicable criteria.

8.1.d. Charts of water quality criteria in Appendix E, Table 1 shall be applied in accordance with major stream and use applications, sections 6 and 7, herein.

8.2. Criteria for Toxicants

8.2.a. Toxicants which are carcinogenic have human health criteria (Water Use Categories A and C) based upon an estimated risk level of one additional cancer case per one million persons (10^{-6}) and are indicated in Appendix E, Table 1 with an endnote ([b]).

8.2.b. A final determination on the critical design flow for carcinogens is not made in this rule, in order to permit further review and study of that issue. Following the conclusion of such review and study, the Legislature may again take up the authorization of this rule for purposes of addressing the critical design flow for carcinogens: Provided, That until such time as the review and study of the issue is concluded or until such time as the Legislature may again take up the authorization of this rule, the regulatory requirements for determining effluent limits for carcinogens shall remain as they were on the date this rule was proposed.

8.3. Criteria for Nutrients in Lakes

8.3.a. This subsection establishes nutrient criteria designed to protect Water Use Categories B and C. The following cool water nutrient criteria shall apply to cool water lakes. (See Appendix F for a representative list.) The following warm water nutrient criteria shall apply to all other lakes with a summer residence time greater than 14 days.

8.3.b. Total phosphorus shall not exceed 50 µg/l for warm water lakes and 30 µg/l for cool water lakes based on an average of four or more samples collected during the period May 1–October 31. In lieu of such sampling, impairment may be evidenced at any time by noncompliance with section 3.2, as determined by the Secretary. Chlorophyll-a shall not exceed 30 µg/l for warm water lakes and 15 µg/l for cool water lakes based on an average of four or more samples collected during the period May 1–October 31. In lieu of such sampling, impairment may be evidenced at any time by noncompliance with section 3.2, as determined by the Secretary.

8.4. Variances from Specific Water Quality Criteria. A variance from numeric criteria may be granted to a discharger if it can be demonstrated that the conditions outlined in paragraphs 6.1.b.1 through 6.1.b.6, herein, limit the attainment of one or more specific water quality criteria. Variances shall apply only to the discharger to whom they are granted and shall be reviewed by the Secretary at least every three years. In granting a variance, the requirements for revision of water quality standards in 46 CSR 6 shall be followed.

8.5. Site-specific numeric criteria. The Secretary may establish numeric criteria different from those set forth in Appendix E, Table 1 for a stream or stream segment upon a demonstration that existing numeric criteria are either over-protective or under-protective of the aquatic life residing in the stream or stream segment. A site-specific numeric criterion will be established only where the numeric criterion will be fully protective of the aquatic life and the existing and designated uses in the stream or stream segment. The site-specific numeric criterion may be established by conducting a Water Effect Ratio study pursuant to the procedures outlined in US EPA's "Interim Guidance on the Determination and Use of Water-Effect Ratios for Metals" (February 1994); other methods may be used with prior approval by the Secretary. In adopting site-specific numeric criteria, the requirements for revision of water quality standards set forth in 46 CSR 6 shall be followed.

§47-2-9. Establishment Of Safe Concentration Values.

When a specific water quality standard has not been established by these rules and there is a discharge or proposed discharge into waters of the State, the use of which has been designated a Category B1, B2, B3 or B4, such discharge may be regulated by the Secretary where necessary to protect State waters through establishment of a safe concentration value as follows:

9.1. Establishment of a safe concentration value shall be based upon data obtained from relevant aquatic field studies, standard bioassay test data which exists in substantial available scientific literature, or data obtained from specific tests utilizing one (1) or more representative important species of aquatic life designated on a case-by-case basis by the Secretary and conducted in a water environment which is equal to or closely approximates that of the natural quality of the receiving waters.

9.2. In those cases where it has been determined that there is insufficient available data to establish a safe concentration value for a pollutant, the safe concentration value shall be determined by applying the appropriate application factor as set forth below to the 96-hour LC 50 value. Except where the Secretary determines, based upon substantial available scientific data that an alternate application factor exists for a pollutant, the following appropriate application factors shall be used in the determination of safe concentration values:

9.2.a. Concentrations of pollutants or combinations of pollutants that are not persistent and not cumulative shall not exceed 0.10 (1/10) of the 96-hour LC 50.

9.2.b. Concentrations of pollutants or combinations of pollutants that are persistent or cumulative shall not exceed 0.01 (1/100) of the 96-hour LC 50.

9.3. Persons seeking issuance of a permit pursuant to these rules authorizing the discharge of a pollutant for which a safe concentration value is to be established using special bioassay tests pursuant to subsection 9.1 of this section shall perform such testing as approved by the Secretary and shall submit all of the following in writing to the Secretary:

9.3.a. A plan proposing the bioassay testing to be performed.

9.3.b. Such periodic progress reports of the testing as may be required by the Secretary.

9.3.c. A report of the completed results of such testing including, but not limited to, all data obtained during the course of testing, and all calculations made in the recording, collection, interpretation and evaluation of such data.

9.4. Bioassay testing shall be conducted in accordance with methodologies outlined in the following documents: U.S. EPA Office of Research and Development Series Publication, Methods for Measuring the Acute Toxicity (EPA/600/4-90/027F, August 1993, 4th Edition) or Short Term Methods for Estimating Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms (EPA/600/4-89/001), March 1989; Standard Methods for the Examination of Water and Wastewater (18th Edition); or ASTM Practice E 729-88 for Conducting Acute Toxicity Tests with Fishes, Macroinvertebrates and Amphibians as published in Volume 11.04 of the 1988 Annual Book of ASTM Standards. Test waters shall be reconstituted according to recommendations and methodologies specified in the previously cited references or methodologies approved in writing by the Secretary.

APPENDIX A
CATEGORY B-2 - TROUT WATERS

This list contains known trout waters and is not intended to exclude any waters which meet the definition in Section 2.19.

River Basin	County	Stream
James River		
J	Monroe	South Fork Potts Creek
Potomac River		
P	Jefferson	Town Run
P	"	Rocky Marsh Run
P	Berkeley	Opequon Creek
P	"	Tuscarora Creek (Above Martinsburg)
P	"	Middle Creek (Above Route 30 Bridge)
P	"	Mill Creek
P	"	Hartland Run
P	"	Mill Run
P	"	Tillance Creek
P	Morgan	Meadow Branch
PS	Jefferson	Flowing Springs Run (Above Halltown)
PS	"	Cattail Run
PS	"	Evitt's Run
PS	"	Big Bullskin Run
PS	"	Long Marsh Run
PC	Hampshire	Cold Stream
PC	"	Edwards Run and Impoundment
PC	"	Dillons Run
PC	Hardy	Lost River
PC	"	Camp Branch
PC	"	Lower Cove Run
PC	"	Moores Run
PC	"	North River (Above Rio)
PC	"	Waites Run
PC	"	Trout Run
PC	"	Trout Pond (Impoundment)
PC	"	Warden Lake (Impoundment)
PC	"	Rock Cliff Lake (Impoundment)
PSB	Hampshire	Mill Creek
PSB	"	Mill Run
PSB	Hardy	Dumpling Creek
PSB	Grant-Pendleton	North Fork South Branch
PSB	Grant	North Fork Lunice Creek
PSB	"	South Fork Lunice Creek
PSB	"	South Mill Creek (Above Hiser)
PSB	"	Spring Run
PSB	Pendleton	Hawes Run (Impoundment)
PSB	"	Little Fork
PSB	"	South Branch (Above North Fork)
PSB	"	Senena Creek
PSB	"	Laurel Fork
PSB	"	Big Run

River Basin	County	Stream
Potomac River		
PNB	Mineral	North Fork Patterson Creek
PNB	"	Fort Ashby (Impoundment)
PNB	"	New Creek
PNB	"	New Creek Dam 14 (Impoundment)
PNB	"	Mill Creek (Above Markwood)
Monongahela River		
M	Monongalia-Marion	Whiteday Creek (Above Smithtown)
MC	Monongalia	Morgan Run
MC	"	Coopers Rock (Impoundment)
MC	"	Blaney Hollow
MC	Preston	Laurel Run
MC	"	Elsey Run
MC	"	Saltlick Creek
MC	"	Buffalo Creek
MC	"	Wolf Creek
MC	Tucker	Clover Run
MC	"	Elklick Run
MC	"	Horseshoe Run
MC	"	Maxwell Run
MC	"	Red Creek
MC	"	Slip Hill Mill Branch
MC	"	Thomas Park (Impoundment)
MC	"	Blackwater River (Above Davis)
MC	"	Blackwater River (Below Davis)
MC	Randolph	Camp Five Run
MC	"	Dry Fork (Above Otter Creek)
MC	"	Glady Fork
MC	"	Laurel Fork
MC	"	Gandy Creek (Above Whitmer)
MC	"	East Fork Glady Fork (Above C & P Compressor Station)
MC	Randolph	Shavers Fork (Above Little Black Fork)
MC	"	Three Spring Run
MC	"	Spruce Knob Lake (Impoundment)
MW	Harrison	Dog Run (Pond)
MW	Lewis	Stonecoal
MT	Barbour	Brushy Fork (Above Valley Furnace)
MT	"	Teter Creek Lake (Impoundment)
MT	"	Mill Run
MT	Taylor-Barbour	Tygart Lake Tailwaters (Above Route 119 Bridge)
MT	Preston	Roaring Creek (Above Little Lick Branch)
MT	Randolph	Tygart River (Above Huttonsville)
MT	"	Elkwater Fork
MT	"	Big Run
MTB	Upshur-Randolph-Lewis	Right Fork Buckhannon River
MTB	Upshur	Buckhannon River (Above Beans Mill)
MTB	Upshur	French Creek

River Basin	County	Stream
Monongahela River		
MTB	Upshur-Randolph	Left Fork Right Fork
MTN	Upshur	Right Fork Middle Fork River
MTM	Randolph	Middle Fork River (Above Cassity)
MY	Preston	Rhine Creek
Little Kanawha River		
LK	Upshur	Left Fork-Right Fork Little Kanawha River)
LK	Upshur-Lewis	Little Kanawha River (Above Wildcat)
Kanawha River		
KE	Braxton	Sutton Reservoir
KE	"	Sutton Lake Tailwaters (Above Route 38/5 Bridge)
KE	Webster	Back Fork
KE	"	Desert Fork
KE	"	Fall Run
KE	"	Laurel Fork
KE	"	Left Fork Holly River
KE	"	Sugar Creek
KE	"	Elk River (Above Webster Springs)
KC	Raleigh	Stephens Lake (Impoundment)
KC	"	Marsh Fork (Above Sundial)
KG	Nicholas	Summersville Reservoir (Impoundment)
KG	"	Summersville Tailwaters (Above Collison Creek)
KG	Nicholas	Deer Creek
KG	Randolph-Webster	Gauley River (Above Moust Coal Tipple)
KG	Fayette	Glade Creek
KG	Nicholas	Hominy Creek
KG	"	Anglins Creek
KG	Greenbrier	Big Clear Creek
KG	"	Little Clear Creek and Laurel Run
KG	"	Meadow Creek
KG	Fayette	Wolf Creek
KG	Nicholas	Cherry River
KG	Greenbrier-Nicholas	Laurel Creek
KG	" "	North Fork Cherry River
KG	Greenbrier	Summit Lake (Impoundment)
KG	Greenbrier-Nicholas	South Fork Cherry River

River Basin	County	Stream
Kanawha River		
KGC	Pocahontas-Webster-Nicholas	Cranberry River
KGC	Pocahontas	South Fork Cranberry River
KGW	Pocahontas	Tea Creek
KGW	Pocahontas-Webster	Williams River (Above Dyer)
KN	Raleigh	Glade Creek
KN	Summers	Meadow Creek
KN	Fayette	Mill Creek
KN	"	Laurel Creek (Above Cotton Hill)
KN	Raleigh	Pinch Creek
KN	Monroe	Rich Creek
KN	"	Turkey Creek
KN	Fayette	Dunloup Creek (Downstream from Harvey Sewage Treatment Plant)
KN	Mercer	East River (Above Kelleysville)
KN	"	Pigeon Creek
KN	Monroe	Laurel Creek
KNG	Monroe	Kitchen Creek (Above Gap Mills)
KNG	Greenbrier	Culverson Creek
KNG	"	Milligan Creek
KNG	Greenbrier-Monroe	Second Creek (Rt. 219 Bridge to Nickell's Mill)
KNG	Greenbrier	North Fork Anthony Creek
KNG	"	Spring Creek
KNG	"	Anthony Creek (Above Big Draft)
KNG	Pocahontas	Watoga Lake
KNG	"	Beaver Creek
KNG	"	Knapp's Creek
KNG	"	Hills Creek
KNG	"	North Fork Deer Creek (Above Route 28/5)
KNG	"	Deer Creek
KNG	"	Sitlington Creek
KNG	"	Stoney Creek
KNG	"	Swago Creek
KNG	"	Buffalo Fork (Impoundment)
KNG	"	Seneca (Impoundment)
KNG	"	Greenbrier River (Above Hosterman)
KNG	"	West Fork-Greenbrier River (Above the impoundment at the tannery)
KNG	"	Little River-East Fork
KNG	"	Little River-West Fork
KNG	"	Five Mile Run
KNG	"	Mullenax Run
KNG	"	Abes Run
KNB	Mercer	Marsh Fork
KNB	"	Camp Creek
OG	Wyoming	Pinnacle creek
BST	McDowell	Dry Fork (Above Canebrake)

APPENDIX B

This list contains known waters used as public water supplies and is not intended to exclude any waters as described in section 6.2, herein.

River Basin	County	Operating Company	Source
Shenandoah River			
S	Jefferson	Charlestown Water	Shenandoah River
Potomac River			
P	Jefferson	3-M Company	Turkey Run
P	"	Shepherdstown Water	Potomac River
P	"	Harpers Ferry Water	Elk Run
P	Berkeley	DuPont Potomac River Works	Potomac River
P	"	Berkeley County PSD	Le Feure Spring
P		Opequon PSD	Quarry Spring
P	"	Hedgesville PSD	Speck Spring
P	Morgan	Paw Paw Water	Potomac River
PSB	Hampshire	Romney Water	South Branch Potomac River
PSB	"	Peterkin Conference Center	Mill Run
PSB	Hardy	Moorefield Municipal Water	South Fork River
PSB	Pendleton	U.S. Naval Radio Sta.	South Fork River
PSB	"	Circleville Water Inc.	North Fork of South Branch, Potomac River
PSB	Grant	Mountain Top PSD	Mill Creek, Impoundment
PSB	"	Petersburg Municipal Water	South Branch, Potomac River
PNB	Grant	Island Creek Coal	Impoundment
PNB	Mineral	Piedmont Municipal Water	Savage River, Maryland
PNB	"	Keyser Water	New Creek
PNB	"	Fort Ashby PSD	Lake
Monongahela River			
M	Monongalia	Morgantown Water Comm.	Colburn Creek & Monongahela River
M	"	Morgantown Ordinance Works	Monongahela River
M	Preston	Preston County PSD	Deckers Creek
M	Monongalia	Blacksville # 1 Mine	Impoundment
M	"	Loveridge Mine	Impoundment
M	"	Consolidation Coal Co.	Impoundment
M	Preston	Mason Town Water	Block Run
MC	Preston	Fibair Inc.	Impoundment
MC	Monongalia	Cheat Neck PSD	Cheat Lake
MC	"	Lakeview County Club	Cheat Lake-Lake Lynn
MC	"	Union Districk PSD	Cheat Lake-Lake Lynn
MC	"	Cooper's Rock State Park	Impoundment

River Basin	County	Operating Company	Source
Monongahela River			
MC	Preston	Kingwood Water	Cheat River
MC	Preston	Hopemount State Hosp.	Snowy Creek
MC	"	Rowlesburg Water	Keyser Run & Cheat River
MC	"	Albright	Cheat River
MC	Tucker	Parsons Water	Shavers & Elk Lick Fork
MC	"	Thomas Municipal	Thomas Reservoir
MC	"	Hamrick PSD	Dry Fork
MC	"	Douglas Water System	Long Run
MC	"	Davis Water	Blackwater River
MC	"	Hambleton Water System	Roaring Creek
MC	"	Canaan Valley State Park	Blackwater River
MC	Pocahontas	Cheat Mt. Sewer	Shavers Lake
MC	"	Snowshoe Co. Water	Shavers Fork
MC	Randolph	Womelsdorf Water	Yokum Run
MW	Harrison	Lumberport Water	Jones Run
MW	"	Clarksburg Water Bd.	West Fork River
MW	"	Bridgeport Mun. Water	Deecons & Hinkle Creek
MW	"	Salem Water Board	Dog Run
MW	"	West Milford Water	West Fork River
MW	Lewis	W.V. Water-Weston District	West Fork River
MW	"	Jackson's Mill Camp	Impoundment
MW	"	West Fork River PSD	West Fork River
MW	"	Kennedy Compresssor Station	West Fork River
MW	"	Jane Lew Water Comm.	Hackers Creek
MW	Harrison	Bel-Meadow Country Club	Lake
MW	"	Harrison Power Station	West Fork River
MW	"	Oakdale Portal	Impoundment
MW	"	Robinson Port	Impoundment
MT	Marion	Fairmont Water Comm.	Tygart River
MT	"	Mannington Water	Impoundment
MT	"	Monongah Water Works	Tygart River
MT	"	Eastern Assoc.	Coal Corp Impoundment
MT	"	Four States Water	Impoundment
MT	Harrison	Shinnston Water Dept.	Tygart River
MT	Taylor	Grafton Water	Tygart River-Lake
MT	Barbour	Phillippi Water	Tygart River
MT	"	Bethlehem Mines Corp.	Impoundment
MT	"	Belington Water Works	Tygart River & Mill Run Lake
MT	Randolph	Elkins Municipal Water	Tygart River
MT	"	Beverly Water	Tygart River
MT	"	Valley Water	Tygart River
MT	"	Huttonsville Medium Security Prison	Tygart River
MT	"	Mill Creek Water	Mill Creek
MTB	Upshur	Buckhannon Water Board	Buckhannon River

River Basin		County	Operating Company	Source
Ohio River				
O	Zone 1	Hancock	Chester Water & Sewer	Ohio River
O	"	Brooke	City of Weirton	Ohio River
O	Zone 1	Brooke	Weirton Steel Division	Ohio River
O	"	Ohio	Wheeling Water	Ohio River
O	"	Tyler	Sistersville Mun. Water	Ohio River
O	"	Pleasants	Pleasants Power Station	Ohio River
O	"	Cabell	Huntington Water Corp.	Ohio River
O	"	Marshall	Mobay Chemical Co.	Ohio River
O	"	Wood	E. I. DuPont	Ohio River
O	Zone 2	Marshall	Meron Water	Glass House Hollow
O	"	"	New Urindahana Water	Wheeling Creek System
O	"	Wetzel	Pine Grove Water	North Fork, Fishing Creek
O	"	Marshall	Consolidated Coal Co.	Impoundment
O	"	Tyler	Middlebourne Water	Middle Island Creek
O	"	Doddridge	West Union Mun. Water	Middle Island Creek
O	"	Mason	Hidden Valley Country	Lake/Impoundment
O	"	Jackson	Ripley Water	Mill Creek
O	"	Wayne	Wayne Municipal Water	Twelve Pole Creek
O	"	"	East Lynn Lake	East Lynn Lake
O	"	"	Monterey Coal Co.	Impoundment
Little Kanawha				
	LK	Wood	Claywood Park PSD	Little Kanawha River
	LK	Calhoun	Grantsville Mun. Water	Little Kanawha River
	LK	Gilmer	Glenville Utility	Little Kanawha River
	LK	"	Consolidated Gas Compressor	Steer Creek
	LK	Braxton	Burnsville Water Works	Little Kanawha River
	LK	Roane	Spencer Water	Spring Creek Mile Tree Reservoir
	LK	Wirt	Elizabeth Water	Little Kanawha River
	LKH	Ritchie	Cairo Water	North Fork Hughes River
	LKH	"	Harrisville Water	North Fork Hughes River
	LKH	"	Pennsboro Water	North Fork Hughes River
Kanawha River				
	K	Putnam	Buffalo Water	Cross Creek
	K	"	Winfield Water	Poplar Fork & Crooked Creek
	K	"	South Putnam PSD	Poplar Fork & Crooked Creek
	K	Kanawha	Cedar Grove Water	Kanawha River
	K	"	Pratt Water	Kanawha River
	K	Fayette	Armstrong PSD PO-K1-CO-EL	Kanawha River & Gum Hollow
	K	"	Kanawha Water Co.-	Unnamed Tributary Kanawha Beards Fork

River Basin	County	Operating Company	Source
Kanawha River			
K	Kanawha	Midland Trail School	Impoundment
K	"	Cedar Coal Co.	Impoundment
K	Fayette	Elkem Metals Co.	Kanawha River
K	Fayette	Deepwater PSD	Kanawha River
K	"	Kanawha Falls PSD	Kanawha River
K	"	W.V. Water-Montgomery	Kanawha River
Pocatalico River			
KP	Kanawha	Sissonville PSD	Pocatalico River
KP	Roane	Walton PSD	Silcott Fork Dam
Coal River			
KC	Kanawha	St. Albans Water	Coal River
KC	"	Washington PSD	Coal River
KC	Lincoln	Lincoln PSD	Coal River
KC	Boone	Coal River PSD	Coal River
KC	"	Whitesville PSD	Coal River
KC	Raleigh	Armco Mine 10	Marsh Fork
KC	"	Armco Steel-Montc. Stickney	Coal River
KC	Raleigh	Peabody Coal	Coal River
KC	"	Stephens Lake Park	Lake Stephens
KC	Boone	W.V. Water-Madison Dist.	Little Coal River
KC	"	Van PSD	Pond Fork
KC	Raleigh	Consol. Coal Co.	Workmans Creek
KC	Boone	Water Ways Park	Coal River
Elk River			
KE	Kanawha	Clendenin Water	Elk River
KE	"	W.V. Water-Kanawha Valley District	Elk River
KE	Kanawha	Pinch PSD	Elk River
KE	Clay	Clay Waterworks	Elk River
KE	"	Procious PSD	Elk River
KE	Braxton	Flatwoods-Canoe Run PSD	Elk River
KE	"	Sugar Creek PSD	Elk River
KE	"	W.V. Water-Gassaway Dist.	Elk River
KE	"	W.V. Water-Sutton Dist.	Elk River
KE	Webster	W.V. Water-Webster Springs	Elk River
KE		Holly River State Park	Holly River
Gauley River			
KG	Nicholas	Craigsville PSD	Gauley River
KG	"	Summersville Water	Impoundment/ Muddlety Creek
KG	"	Nettie-Leivasy PSD	Jim Branch
KG	Webster	Cowen PSD	Gauley River
KG	Nicholas	Wilderness PSD	Anglins Creek & Meadow River
KG	"	Richwood Water	North Fork Cherry River

River Basin	County	Operating Company	Source
New River			
KN	Fayette	Ames Heights Water	Mill Creek
KN	"	Mt. Hope Water	Impounded Mine (Surface)
KN	Fayette	Ansted Municipal Water	Mill Creek
KN	"	Fayette Co. Park	Impoundment
KN	"	New River Gorge Campground	Impoundment
KN	"	Fayetteville Water	Wolfe Creek
KN	Raleigh	Beckley Water	Glade Creek
KN	"	Westmoreland Coal Co.	Farley Branch
Bluestone River			
KNB	Summers	Jumping Branch-Nimitz	Mt. Valley Lake
KNB	"	Bluestone Conf. Center	Bluestone Lake
KNB	"	Pipestem State Park	Impoundment
KNB	Mercer	Town of Athens	Impoundment
KNB	"	Bluewell PSD	Impoundment
KNB	"	Bramwell Water	Impoundment
KNB	"	Green Valley-Glenwood PSD	Bailey Reservoir
KNB	"	Kelly's Tank	Spring
KNB	"	W.V. Water Princeton	Impoundment/ Brusch Creek
KNB	"	Lashmeet PSD	Impoundment
KNB	"	Pinnacle Water Assoc.	Mine
KNB	"	W.V. Water Bluefield	Impoundment
Greenbrier River			
KNG	Summers	W.V. Water Hinton	Greenbrier River & New River
KNG	"	Big Bend PSD	Greenbrier River
KNG	Greenbrier	Alderson Water Dept.	Greenbrier River
KNG	"	Ronceverte Water	Greenbrier River
KNG	"	Lewisburg Water	Greenbrier River
KNG	Pocahontas	Denmar State Hospital Water	Greenbrier River
KNG	"	City of Marlinton Water	Knapp Creek
KNG	"	Cass Scenic Railroad	Leatherbark Creek
KNG	"	Upper Greenbrier PSD	Greenbrier River
KNG	"	The Hermitage	Greenbrier River
Guyandotte River			
OG	Cabell	Salt Rock PSD	Guyandotte River
OG	Lincoln	West Hamlin Water	Guyandotte River
OG	Logan	Logan Water Board	Guyandotte River
OG	"	Man Water Works	Guyandotte River
OG	"	Buffalo Creek PSD	Buffalo Creek/ Mine/Wells
OG	Logan	Chapmanville	Guyandotte River
OG	"	Logan PSD	Whitman Creek/ Guyandotte River
OG	Mingo	Gilbert Water	Guyandotte River
OG	Wyoming	Oceana Water	Laurel Fork
OG	"	Glen Rogers PSD	Impoundment

River Basin	County	Operating Company	Source
Guyandotte River			
OG	Wyoming	Pineville Water	Pinnacle Creek/
OG	Raleigh	Raleigh Co. PSD-Amigo	Tommy Creek
OMG	Cabell	Milton Water Works	Guyandotte River
OMG	"	Culloden PSD	Indian Fork Creek
OMG	Putnam	Hurricane Municipal Water	Impoundment
OMG	Putnam	Lake Washington PSD	Lake Washington
Big Sandy River			
BS	Wayne	Kenova Municipal Water	Big Sandy River
BS	"	Fort Gay Water	Tug Fork
BST	Mingo	Kermit Water	Tug Fork
BST	"	Matewan Water	Tug Fork
BST	"	A & H Coal Co., Inc.	Impoundment
BST	"	Williamson Water	Impoundment
BST	McDowell	City of Welch	Impoundment/Wells
BST	"	City of Gary	Impoundment/Mine

APPENDIX C
CATEGORY E-3 - POWER PRODUCTION

This list contains known power production facilities and is not intended to exclude any waters as described in section 6.6.c, herein.

River Basin	County	Station Name	Operating Company
Monongahela River			
M	Monongalia	Fort Martin Power Station	Monongahela Power
M	Marion	Rivesville Station	Monongahela Power
MC	Preston	Albright Station	Monongahela Power
Potomac	Grant	Mt. Storm Power Station	Virginia Electric & Power Company
Ohio River			
O - Zone 1	Wetzel	Hannibal (Hydro)	Ohio Power
O " "	Marshall	Kammer	Ohio Power
O " "	"	Mitchell	Ohio Power
O " "	Pleasants	Pleasants Station	Monongahela Power
O " "	"	Willow Island Station	Monongahela Power
O " "	Mason	Phillip Sporn Plant	Central Operating (AEP)
O " "	"	Racine (Hydro)	Ohio Power
O " "	"	Mountaineer	Appalachian Power Co.
K	Putnam	Winfield (Hydro)	Appalachian Power Co.
K	Kanawha	Marmet (Hydro)	Appalachian Power Co.
K	"	London (Hydro)	Appalachian Power Co.
K	"	Kanawha River	Appalachian Power Co.
K	"	John E. Amos	Appalachian Power Co.

APPENDIX D
CATEGORY C - WATER CONTACT RECREATION

This list contains waters known to be used for water contact recreation and is not intended to exclude any waters as described in section 6.4, herein.

River Basin	Stream Code	Stream	County
Shenandoah	S	Shenandoah River	Jefferson
Potomac	P	Potomac River	Jefferson
	P	" "	Hampshire
	P	" "	Berkeley
	P	" "	Morgan
	P-9	Sleepy Creek & Meadow Branch	Berkeley
	P-9-G-1	North Fork of Indian Run	Morgan
South Branch	PSB	South Branch of Potomac River	Hampshire
	PSB	" "	Hardy
	PSB	" "	Grant
	PSB-21-X	Hawes Run	Pendleton
	PSB-25-C-2	Spring Run	Grant
	PSB-28	North Fork South Branch Potomac River	Grant
North Branch	PNB	North Branch of Potomac River	Mineral
	PNB-4-EE	North Fork Patterson Creek	Grant
	PNB-7-H	Linton Creek	Grant
	PNB-17	Stoney River-Mt. Storm Lake	Grant
	PC	Cacapon River	Hampshire
Monongalia			
Cheat	MC	Cheat Lake/Cheat river	Monongalia/Preston
	MC	Alpine Lake	Preston
	MC-6	Coopers Rock Lake/ Quarry Run	Monongalia
	MC-12	Big Sandy Creek	Preston
	MSC	Shavers Fork	Randolph
	MTN	Middle Fork River	Barbour/Randolph/ Upshur
	MW	West Fork River	Harrison
	MW-18	Stonecoal Creek/ Stonecoal Lake	Lewis

River Basin	Stream Code	Stream	County
Ohio	O	OhioRiver	Brooke/Cabell/ Hancock/Jackson/ Marshall/Mason/Ohio/ Pleasants/Tyler/ Wayne/Wood/Wetzel
	O-2-H	Beech Fork of Twelvepole Creek/Beech Fork Lake	Wayne
	O-2-Q	East Fork of Twelvepole Creek/East Lynn Lake	Wayne
	O-3	Fourpole Creek	Cabell
	O-21	Old Town Creek/ McClintic Ponds	Mason
	OMI	Middle Island Creek/ Crystal Lake	Doddridge
	OG	Guyandotte River	Cabell
	OG	Guyandotte River/ R. D. Bailey Lake	Wyoming
	OGM	Mud River	Cabell
Little Kanawha	LK	Little Kanawha River/ Burnsville Lake	Braxton
Kanawha	K	Kanawha River	Fayette/Kanawha/ Mason/Putnam
	K-1	Unnamed Tributary Krodel Lake	Mason
	KC	Coal River	Kanawha
	KC-45-Q	Stephens Branch/ Lake Stephens	Raleigh
	KE	Elk River	Kanawha/Clay/ Braxton/Webster/ Randolph
	KE	Sutton lake	Braxton
	KN	New River	Fayette/Raleigh/ Summers
	KN-26-F	Little Beaver Creek	Raleigh
	KNG	Greenbrier River	Greenbrier/ Pocahontas/Summers
	KNG-23-E-1	Little Devil Creek/ Moncove Lake	Monroe
	KNG-28	Anthony Creek	Greenbrier
	KNG-28-P	Meadow Creek/ Lake Sherwood	Greenbrier
	KNB	Bluestone River/ Bluestone Lake	Summers
	KG	Gauley River	Webster

River Basin	Stream Code	Stream	County
Kanawha	KG	Gauley River/ Summersville Lake	Nicholas
	KGW	Williams River	Webster

APPENDIX E, TABLE 1

PARAMETER	USE DESIGNATION						
	AQUATIC LIFE				HUMAN HEALTH		ALL OTHER USES
	B1, B4		B2		C[3]	A[4]	
	ACUTE[1]	CHRON[2]	ACUTE[1]	CHRON[2]			
8.1 Dissolved Aluminum (ug/l)	750xCF[5]	750xCF[5]	750xCF[5]	87xCF[5]			
8.2. Acute and chronic aquatic life criteria for ammonia shall be determined using the National Criterion for Ammonia in Fresh Water[d] from USEPA's 1999 Update of Ambient Water Quality Criteria for Ammonia (EPA-822-R-99-014, December 1999)	X	X	X	X			
8.3 Antimony (ug/l)					4300	14	
8.4 Arsenic (ug/l)					10	10	100
8.4.1 Dissolved Trivalent Arsenic (ug/l)	340	150	340	150			
8.5 Barium (mg/l)						1.0	
8.6 Beryllium (ug/l)	130		130			.0077	
8.7 Cadmium (ug/l) Hardness (mg/l $CaCO_3$) — Soluble Cd 0 - 35 — 1.0 36 - 75 — 2.0 76 - 150 — 5.0 > 150 — 10.0						X	
8.7.1 10 ug/l in the Ohio River (O Zone 1) main stem (see section 7.1.d, herein)						X	

APPENDIX E, TABLE 1

PARAMETER	USE DESIGNATION						
	AQUATIC LIFE				HUMAN HEALTH		ALL OTHER USES
	B1, B4		B2		C[3]	A[4]	
	ACUTE[1]	CHRON[2]	ACUTE[1]	CHRON[2]			
8.7.2 The four-day average concentration of dissolved cadmium determined by the following equation: $Cd = e^{(0.7409[\ln(hardness)]-4.719)} \times CF^5$		X		X			
8.7.3 The one-hour average concentration of dissolved cadmium determined by the following equation: $Cd = e^{(1.0166[\ln(hardness)]-3.924)} \times CF^5$	X		X				
8.8 Chloride (mg/l)	860	230	860	230	250	250	
8.9.1 Chromium, dissolved hexavalent (ug/l):	16	11	16	7.2		50	
8.9.2 Chromium, trivalent (ug/l) The one-hour average concentration of dissolved trivalent chromium determined by the following equation: $CrIII = e^{(0.8190[\ln(hardness)]+3.7256)} \times CF^5$	X		X				
8.9.3 The four-day average concentration of dissolved trivalent chromium determined by the following concentration: $CrIII = e^{(0.8190[\ln(hardness)]+0.6848)} \times CF^5$		X		X			
8.10 Copper (ug/l)						1000	
8.10.1 The four-day average concentration of dissolved copper determined by the following equation[a]: $Cu = e^{(0.8545[\ln(hardness)]-1.702)} \times CF^5$		X		X			

APPENDIX E, TABLE 1

PARAMETER	USE DESIGNATION						
	AQUATIC LIFE				HUMAN HEALTH		ALL OTHER USES
	B1, B4		B2		C[3]	A[4]	
	ACUTE[1]	CHRON[2]	ACUTE[1]	CHRON[2]			
8.10.2 The one-hour average concentration of dissolved copper determined by the following equation[a]: $Cu = e^{(0.9422[\ln(hardness)]-1.700)} \times CF^5$	X		X				
8.11 Cyanide (ug/l) (As free cyanide $HCN+CN^-$)	22	5.0	22	5.0	5.0	5.0	
8.12 Dissolved Oxygen[c]: not less than 5 mg/l at any time.	X				X	X	X
8.12.1 Kanawha River main stem, Zone 1 - Not less than 4.0 mg/l at any time.	X						
8.12.2 Ohio River main stem - the average concentration shall not be less than 5.0 mg/l per calendar day and shall not be less than 4.0 mg/l at any time or place outside any established mixing zone - provided that a minimum of 5.0 mg/l at any time is maintained during the April 15-June 15 spawning season.	X						
8.12.3 Not less than 7.0 mg/l in spawning areas and in no case less than 6.0 mg/l at any time.			X				

APPENDIX E, TABLE 1

PARAMETER	USE DESIGNATION						
	AQUATIC LIFE				HUMAN HEALTH		ALL OTHER USES
	B1, B4		B2		C[3]	A[4]	
	ACUTE[1]	CHRON[2]	ACUTE[1]	CHRON[2]			
8.13 Fecal Coliform: Maximum allowable level of fecal coliform content for Water Contact Recreation (either MPN or MF) shall not exceed 200/100 ml as a monthly geometric mean based on not less than 5 samples per month; nor to exceed 400/100 ml in more than ten percent of all samples taken during the month.					X	X	
8.13.1 Ohio River main stem (zone 1) - During the non-recreational season (November through April only) the maximum allowable level of fecal coliform for the Ohio River (either MPN or MF) shall not exceed 2000/100 ml as a monthly geometric mean based on not less than 5 samples per month.					X	X	
8.14 Fluoride (mg/l)						1.4	
8.14.1 Not to exceed 2.0 for category D1 uses.							X
8.15 Iron[c] (mg/l)		1.5		0.5		1.5	
8.16 Lead (ug/l)						50	
8.16.1 The four-day average concentration of dissolved lead determined by the following equation[a]: $Pb = e^{(1.273[\ln(hardness)]-4.705)} \times CF^5$		X		X			

APPENDIX E, TABLE 1

PARAMETER	USE DESIGNATION						
	AQUATIC LIFE				HUMAN HEALTH		ALL OTHER USES
	B1, B4		B2		C[3]	A[4]	
	ACUTE[1]	CHRON[2]	ACUTE[1]	CHRON[2]			
8.16.2 The one-hour average concentration of dissolved lead determined by the following equation[a]: $Pb = e^{(1.273[\ln(\text{hardness})]-1.46)} \times CF^5$	X		X				
8.17 Manganese (mg/l) (see §6.2.d)						1.0	
8.18 Mercury The total organism body burden of any aquatic species shall not exceed 0.5 ug/g as methylmercury.					0.5	0.5	
8.18.1 Total mercury in any unfiltered water sample (ug/l):	2.4		2.4		0.15	0.14	
8.18.2 Methylmercury (water column) (ug/l):		.012		.012			
Nickel (ug/l)					4600	510	
8.19.1 The four-day average concentration of dissolved nickel determined by the following equation[a]: $Ni = e^{(0.846[\ln(\text{hardness})]+0.0584)} \times CF^5$		X		X			
8.19.2 The one-hour average concentration of dissolved nickel determined by the following equation[a]: $Ni = e^{(0.846[\ln(\text{hardness})]+2.255)} \times CF^5$	X		X				
8.20 Nitrate (as Nitrate-N) (mg/l)						10	
8.21 Nitrite (as Nitrite-N) (mg/l)	1.0		.060				

APPENDIX E, TABLE 1

PARAMETER	USE DESIGNATION						
	AQUATIC LIFE				HUMAN HEALTH		ALL OTHER USES
	B1, B4		B2		C[3]	A[4]	
	ACUTE[1]	CHRON[2]	ACUTE[1]	CHRON[2]			
8.22 Nutrients							
Chlorophyll –a (µg/l) (see §47-2-8.3)							
Total Phosphorus (µg/l) (see §47-2-8.3)							
8.23 Organics							
Chlordane[b] (ng/l)	2400	4.3	2400	4.3	0.46	0.46	0.46
DDT[b] (ng/l)	1100	1.0	1100	1.0	0.024	0.024	0.024
Aldrin[b] (ng/l)	3.0		3.0		0.071	0.071	0.071
Dieldrin[b] (ng/l)	2500	1.9	2500	1.9	0.071	0.071	0.071
Endrin (ng/l)	180	2.3	180	2.3	2.3	2.3	2.3
Toxaphene[b] (ng/l)	730	0.2	730	0.2	0.73	0.73	0.73
PCB[b] (ng/l)		14.0		14.0	0.045	0.044	0.045
Methoxychlor (ug/l)		0.03		0.03	0.03	0.03	0.03
Dioxin (2,3,7,8- TCDD)[b] (pg/l)					0.014	0.013	0.014
Acrylonitrile[b] (ug/l)					0.66	0.059	
Benzene[b] (ug/l)					51	0.66	
1,2-dichlorobenzene (mg/l)					17	2.7	
1,3-dichlorobenzene (mg/l)					2.6	0.4	
1,4-dichlorobenzene (mg/l)					2.6	0.4	
2,4-dinitrotoluene[b] (ug/l)					9.1	0.11	
Hexachlorobenzene[b] (ng/l)					0.77	0.72	

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APPENDIX E, TABLE 1

PARAMETER	USE DESIGNATION						
	AQUATIC LIFE				HUMAN HEALTH		ALL OTHER USES
	B1, B4		B2		C[3]	A[4]	
	ACUTE[1]	CHRON[2]	ACUTE[1]	CHRON[2]			
Carbon tetrachloride[b] (ug/l)					4.4	0.25	
Chloroform[b] (ug/l)					470	5.7	
Bromoform[b] (ug/l)					140	4.3	
Dichlorobromomethane[b] (ug/l)					17	0.55	
Methyl Bromide (ug/l)					1500	47	
Methylene Chloride[b] (ug/l)					590	4.6	
1,2-dichloroethane[b] (ug/l)					99	0.035	
1,1,1- trichloroethane[b] (mg/l)						12	
1,1,2,2-tetrachloroethane (ug/l)					11	0.17	
1,1-dichloroethylene[b] (ug/l)					3.2	0.03	
Trichloroethylene[b] (ug/l)					81	2.7	
Tetrachloroethylene[b] (ug/l)					8.85	0.8	
Toluene[b] (mg/l)					200	6.8	
Acenaphthene (ug/l)					990	670	

APPENDIX E, TABLE 1

PARAMETER	USE DESIGNATION						
	AQUATIC LIFE				HUMAN HEALTH		ALL OTHER USES
	B1, B4		B2		C[3]	A[4]	
	ACUTE[1]	CHRON[2]	ACUTE[1]	CHRON[2]			
Anthracene (ug/l)					40,000	8,300	
Benzo(a) Anthracene[b] (ug/l)					0.018	0.0038	
Benzo(a) Pyrene[b] (ug/l)					0.018	0.0038	
Benzo(b) Fluoranthene[b] (ug/l)					0.018	0.0038	
Benzo(k) Fluoranthene[b] (ug/l)					0.018	0.0038	
Chrysene[b] (ug/l)					0.018	0.0038	
Dibenzo(a,h)Anthracene[b] (ug/l)					0.018	0.0038	
Fluorene (ug/l)					5300	1100	
Ideno(1,2,3-cd)Pyrene[b] (ug/l)					0.018	0.0038	
Pyrene (ug/l)					4000	830	
2-Chloronaphthalene (ug/l)					1600	1000	
Phthalate esters[6] (ug/l)		3.0		3.0			
Vinyl chloride[b] (chloroethene) (ug/l)					525	2.0	
alpa-BHC (alpha- Hexachloro-cyclohexane)[b] (ug/l)					0.013	.0039	
beta-BHC(beta- Hexachloro-cyclohexane)[b] (ug/l)					0.046	0.014	
gamma-BHC (gamma- Hexachloro-cyclohexane)[b] (ug/l)	2.0	0.08	2.0	0.08	0.063	0.019	
Chlorobenzene (mg/l)					21	0.68	
Ethylbenzene (mg/l)					29	3.1	
Heptachlor[b] (ng/l)	520	3.8	520	3.8	0.21	0.21	

APPENDIX E, TABLE 1

PARAMETER	USE DESIGNATION						
	AQUATIC LIFE				HUMAN HEALTH		ALL OTHER USES
	B1, B4		B2		C[3]	A[4]	
	ACUTE[1]	CHRON[2]	ACUTE[1]	CHRON[2]			
2-methyl-4,6-Dinitrophenol (ug/l)					765	13.4	
Fluoranthene (ug/l)					370	300	
8.23.1 When the specified criteria for organic chemicals listed in §8.23 are less than the practical laboratory quantification level, instream values will be calculated from discharge concentrations and flow rates, where applicable.							
8.24 pH[c] No values below 6.0 nor above 9.0. Higher values due to photosynthetic activity may be tolerated.	X	X	X	X	X	X	X
8.25 Phenolic Materials							
8.25.1 Phenol (ug/l)					4,600,000	21,000	
8.25.2 2-Chlorophenol (ug/l)					400	120	
8.25.3 2,4-Dichlorophenol (ug/l)					790	93	
8.25.4 2,4-Dimethylphenol (ug/l)					2300	540	
8.25.5 2,4-Dinitrophenol (ug/l)					14,000	70	
8.25.6 Pentachlorophenol[b] (ug/l)					8.2	0.28	
8.25.6.a The one-hour average concentration of pentachlorophenol determined by the following equation: exp(1.005(pH)-4.869)	X		X				

APPENDIX E, TABLE 1

PARAMETER	USE DESIGNATION						
	AQUATIC LIFE				HUMAN HEALTH		ALL OTHER USES
	B1, B4		B2		C[3]	A[4]	
	ACUTE[1]	CHRON[2]	ACUTE[1]	CHRON[2]			
8.25.6.b The 4-day average concentration of pentachlorophenol determined by the following equation: exp(1.005(pH)-5.134).		X		X			
8.25.7 2,4,6-Trichlorophenol[b] (ug/l)-					6.5	2.1	
8.26 Radioactivity: Gross Beta activity not to exceed 1000 picocuries per liter (pCi/l), nor shall activity from dissolved strontium-90 exceed 10 pCi/l, nor shall activity from dissolved alpha emitters exceed 3 pCi/l.	X		X		X	X	X
8.26.1 Gross total alpha particle activity (including radium-226 but excluding radon and uranium shall not exceed 15 pCi/l and combined radium-226 and radium-228 shall not exceed 5pCi/l; provided that the specific determination of radium-226 and radium-228 are not required if dissolved particle activity does not exceed 5pCi/l; the concentration of tritium shall not exceed 20,000 pCi/l; the concentration of total strontium-90 shall not exceed 8 pCi/l in the Ohio River main stem.	X		X		X	X	X
8.27 Selenium (ug/l)	20	5	20	5		50	

APPENDIX E, TABLE 1

PARAMETER	USE DESIGNATION						
	AQUATIC LIFE				HUMAN HEALTH		ALL OTHER USES
	B1, B4		B2		C[3]	A[4]	
	ACUTE[1]	CHRON[2]	ACUTE[1]	CHRON[2]			
8.28 Silver (ug/l) Hardness Silver 0-50 1 51-100 4 101-200 12 >201 24				X		X	
8.28.1 0-50 1 51-100 4 101-200 12 201-400 24 401-500 30 501-600 43		X					
8.28.2 The one-hour average concentration of dissolved silver determined by the following equation: $Ag=e^{(1.72[\ln(hardness)]-6.59)} \times CF^5$	X		X				

APPENDIX E, TABLE 1

PARAMETER	USE DESIGNATION						
	AQUATIC LIFE				HUMAN HEALTH		ALL OTHER USES
	B1, B4		B2		C[3]	A[4]	
	ACUTE[1]	CHRON[2]	ACUTE[1]	CHRON[2]			
8.29 Temperature Temperature rise shall be limited to no more than 5°F above natural temperature, not to exceed 87°F at any time during months of May through November and not to exceed 73°F at any time during the months of December through April. During any month of the year, heat should not be added to a stream in excess of the amount that will raise the temperature of the water more than 5°F above natural temperature. In lakes and reservoirs, the temperature of the epilimnion should not be raised more than 3°F by the addition of heat of artificial origin. The normal daily and seasonable temperature fluctuations that existed before the addition of heat due to other natural causes should be maintained.	X						
8.29.1 For the Kanawha River Main Stem (K-1): Temperature rise shall be limited to no more than 5°F above natural temperature, not to exceed 90°F in any case.	X						

APPENDIX E, TABLE 1

PARAMETER	USE DESIGNATION						
	AQUATIC LIFE				HUMAN HEALTH		ALL OTHER USES
	B1, B4		B2		C[3]	A[4]	
	ACUTE[1]	CHRON[2]	ACUTE[1]	CHRON[2]			
8.29.2 For the Bluestone R (KNB), Bluestone Lake (KN-60) East River (KNE), New River (KN), Gauley R. (KG) and Greenbrier River (KNG): Temperature rise shall be limited to no more than 5°F above natural temperature, not to exceed 81°F at any time during the months of May through November and not to exceed 73°F at any time during December through April.			X				
8.29.3 No heated effluents will be discharged in the vicinity of spawning areas. The maximum temperatures for cold waters are expressed in the following table: Daily Mean °F / Hourly Max °F Oct-Apr 50 55 Sep-May 58 62 Jun-Aug 66 70			X				

APPENDIX E, TABLE 1

PARAMETER	USE DESIGNATION						
	AQUATIC LIFE				HUMAN HEALTH		ALL OTHER USES
	B1, B4		B2		C[3]	A[4]	
	ACUTE[1]	CHRON[2]	ACUTE[1]	CHRON[2]			
8.29.4 For Ohio River Main Stem (01) (see section 7.1.d, herein): Dates / Period Ave. / Inst. Max. Jan 1-31 45°F 50°F February 45 50 March 1-15 51 56 March 16-31 54 59 April 1-15 58 64 April 16-30 64 69 May 1-15 68 73 May 16-31 75 80 June 1-15 80 85 June 16-30 83 87 July 1-31 84 89 August 1-31 84 89 Sept 1-15 84 87 Sept 16-30 82 86 Oct 1-15 77 82 Oct 16-31 72 77 Nov 1-30 67 72 Dec 1-31 52 57	X						
8.30 Thallium (ug/l)					6.3	1.7	
8.31 Threshold odor[c] Not to exceed a threshold odor number of 8 at 104°F as a daily average.		X		X	X	X	
8.32 Total Residual Chlorine (ug/l - measured by amperometric or equivalent method)	19	11					
8.32.1 No chlorinated discharge allowed			X				

APPENDIX E, TABLE 1

PARAMETER	USE DESIGNATION						
	AQUATIC LIFE				HUMAN HEALTH		ALL OTHER USES
	B1, B4		B2		C[3]	A[4]	
	ACUTE[1]	CHRON[2]	ACUTE[1]	CHRON[2]			
8.33 Turbidity No point or non-point source to West Virginia's waters shall contribute a net load of suspended matter such that the turbidity exceeds 10 NTU's over background turbidity when the background is 50 NTU or less, or have more than a 10% increase in turbidity (plus 10 NTU minimum) when the background turbidity is more than 50 NTUs. This limitation shall apply to all earth disturbance activities and shall be determined by measuring stream quality directly above and below the area where drainage from such activity enters the affected stream. Any earth disturbing activity continuously or intermittently carried on by the same or associated persons on the same stream or tributary segment shall be allowed a single net loading increase.		X		X	X	X	
8.33.1 This rule shall not apply to those activities at which Best Management Practices in accordance with the State's adopted 208 Water Quality Management Plan are being utilized, maintained and completed on a site-specific basis as determined by the appropriate 208 cooperative or an approved Federal or State Surface Mining Permit is in effect. This exemption shall not apply to Trout Waters.		X			X	X	

APPENDIX E, TABLE 1

PARAMETER	USE DESIGNATION						
	AQUATIC LIFE				HUMAN HEALTH		ALL OTHER USES
	B1, B4		B2		C[3]	A[4]	
	ACUTE[1]	CHRON[2]	ACUTE[1]	CHRON[2]			
8.34 Zinc (ug/l) The four-day average concentration of dissolved zinc determined by the following equation[a]: $Zn = e^{(0.8473[\ln(hardness)]+0.884)} \times CF^5$		X		X			
8.34.1 The one-hour average concentration of dissolved zinc determined by the following equation[a]: $Zn = e^{(0.8473[\ln(hardness)]+0.884)} \times CF^5$	X		X				

[1] One hour average concentration not to be exceeded more than once every three years on the average, unless otherwise noted.
[2] Four-day average concentration not to be exceeded more than once every three years on the average, unless otherwise noted.
[3] These criteria have been calculated to protect human health from toxic effects through fish consumption, unless otherwise noted. Concentration not to be exceeded, unless otherwise noted.
[4] These criteria have been calculated to protect human health from toxic effects through drinking water and fish consumption, unless otherwise noted. Concentration not to be exceeded, unless otherwise noted.
[5] The appropriate Conversion Factor (CF) is a value used as a multiplier to derive the dissolved aquatic life criterion is found in Appendix E, Table 2.
[6] Phthalate esters are determined by the summation of the concentrations of Butylbenzyl Phthalate, Diethyl Phthalate, Dimethyl Phthalate, Di-n-Butyl Phthalate and Di-n-Octyl Phthalate.
[a] Hardness as calcium carbonate (mg/l). The minimum hardness allowed for use is this equation shall not be less than 25 mg/l, even if the actual ambient hardness is less than 25 mg/l. The maximum hardness value for use in this equation shall not exceed 400 mg/l even if the actual hardness is greater than 400 mg/l.
[b] Known or suspected carcinogen. Human health standards are for a risk level of 10^{-6}.
[c] May not be applicable to wetlands (B4) - site-specific criteria are desirable.
[d] The early life stage equation in the National Criterion shall be used to establish chronic criteria throughout the state unless the applicant demonstrates that no early life stages of fish occur in the affected water(s).

APPENDIX E
TABLE 2

Conversion Factors

Metal	Acute	Chronic
Aluminum	1.000	1.000
Arsenic (III)	1.000	1.000
Cadmium	1.136672-[(ln hardness)(0.041838)]	1.101672-[(ln hardness)(0.041838)]
Chromium (III)	0.316	0.860
Chromium(VI)	0.982	0.962
Copper	0.960	0.960
Lead	1.46203-[(ln hardness)(0.145712)]	1.46203-[(ln hardness)(0.145712)]
Nickel	0.998	0.997
Silver	0.85	N/A
Zinc	0.978	0.986

APPENDIX F
COOL WATER LAKES

This list contains lakes to be managed for cool water fisheries and is not intended to exclude any waters which meet the definition in Section 2.2.

River Basin	County	Lake
Potomac River		
PC	Hardy Lost River	Trout Pond (Impoundment)
PC	Hardy Lost River	Rock Cliff Lake (Impoundment)
PSB	Pendleton	Hawes Run (Impoundment)
PNB	Mineral	New Creek Dam 14(Impoundment)
Monongahela River		
MC	Monongalia	Coopers Rock (Impoundment)
MC	Monongalia	Cheat Lake
MC	Tucker	Thomas Park (Impoundment)
MC	Randolph	Spruce Knob Lake (Impoundment)
MT	Taylor	Tygart Lake
MW	Lewis	Stonecoal Lake
Kanawha River		
KC	Raleigh	Stephens Lake (Impoundment)
KG	Nicholas	Summersville Reservoir (Impoundment)
KG	Greenbrier	Summit Lake (Impoundment)
KNG	Pocahontas	Watoga Lake
KNG	Pocahontas	Buffalo Fork (Impoundment)
KNG	Pocahontas	Seneca (Impoundment)
KCG	Pocahontas	Handley Pond
Guyandotte River		
OG	Wyoming/Mingo	RD Bailey Lake

ATTACHMENT

D

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

JAN 9 2006

Lisa McClung, Director
Water and Waste Management Division
West Virginia Department of Environmental Protection
601 57th Street, S.E.
Charleston, West Virginia 25304

Dear ~~Ms. McClung~~ Lisa:

The West Virginia Environmental Quality Board (EQB) submitted complete packages in support of a revision to its *Requirements Governing Water Quality Standards* (WQS regulations) to the U.S. Environmental Protection Agency (EPA), on January 13, 2005, and May 23, 2005.[1] The State submitted this revision for EPA review, pursuant to Section 303(c)(1) of the Clean Water Act (CWA) and 40 C.F.R. Part 131. In the first submission, the revision was adopted through an emergency rule. Following the emergency rule, the West Virginia Legislature enacted the revision as a permanent modification of the regulations. The WQS regulations as modified by the Legislature were then resubmitted to EPA.

The revision to the West Virginia WQS regulations temporarily modifies the chronic aluminum criterion from 87 μg/L to 750 μg/L for all waters except for trout waters (in trout waters, the chronic aluminum criterion of 87 μg/L continues to apply). The purpose of this letter is to approve West Virginia's revised aluminum criteria as consistent with the requirements of the CWA and the applicable Federal regulations at 40 C.F.R Part 131. The specific provision that EPA is approving in accordance with Section 303(c)(3) of the CWA and 40 C.F.R. Part 131 and the rationale for the approval are enclosed with this letter. West Virginia's revised Water Quality Standards approved today are now effective for CWA purposes.

Please note that the State regulatory language provides that the modification of the aluminum chronic criteria apply only until July 4, 2007. Under the State regulations, in July 4, 2007, the chronic criterion will revert to 87 ug/L dissolved aluminum applicable in all waters,

[1] The submissions by West Virginia were deemed complete when EPA received the certification from the State Attorney General that the revisions were duly adopted pursuant to State law. See 40 C.F.R. 131.6. EPA received West Virginia's Letter of Certification on May 26, 2005.

which was previously approved by EPA. Nonetheless, EPA's approval of the criteria as modified is based on a finding that the criteria are protective of the aquatic life use regardless of whether they apply temporarily or permanently.

Under the Endangered Species Act (ESA), EPA has the obligation to determine if our approval of this modification to West Virginia's Water Quality Standards regulation will adversely affect threatened and endangered species and their critical habitat in West Virginia. EPA has initiated the consultation process required under Section 7(a)(2) of the ESA. As part of this process, EPA has conducted a biological evaluation that finds that our approval action will not likely adversely affect these species or their critical habits. We are approving the West Virginia revised aluminum criteria pending completion of ESA section 7(a)(2) consultation with the U.S. Fish and Wildlife Service. Please note that in approving West Virginia criteria subject to the consultation, EPA may need to revise its approval decision if the consultation identifies a situation where the approved criteria may not be adequate.

If you have any questions concerning this letter please contact Ms. Cheryl Atkinson at (215) 814 3392.

Sincerely,

Jon M. Capacasa

Jon M. Capacasa, Director
Water Protection Division

EPA Region III Approval Rationale
West Virginia Amendments
Virginia Title Legislative Rule Series 1
Requirements Governing Water Quality Standard

The revision to the aluminum criteria submitted by West Virginia to EPA consists of a footnote applicable to the aluminum chronic criteria, which reads:

> e. Until July 4, 2007, the aluminum criteria will be implemented as follows: the chronic aluminum criterion shall be 87 $\mu g/l$ for trout waters (as defined in section 2.20 of this rule)[2] and shall be 750 $\mu g/l$ for all other water of the states. The implementation of the interim criteria provides time for a study to develop aluminum criteria for water of the state, which are based upon sound science and are protective of aquatic life.

Prior to this revision, West Virginia regulations included EPA-approved acute and chronic aluminum criteria of 750 $\mu g/L$ and 87 $\mu g/L$ dissolved aluminum respectively, applicable to all waters designated for aquatic life use.[3] The effect of the revision is to amend the aluminum criteria as follows:

- Freshwater Acute Criterion = 750 $\mu g/L$ dissolved aluminum (applicable in all waters) and,
- Freshwater Chronic Criteria = 87 $\mu g/L$ dissolved aluminum (applicable in trout waters only) and 750 $\mu g/L$ dissolved Aluminum (applicable in non-trout waters).

West Virginia modified its aluminum criteria thus, in light of stream data presented by the WV Department of Environmental Protection, which purports to show, that waters that are considered impaired based on the chronic aluminum criterion of 87 $\mu g/l$ have thriving aquatic communities and have no physical signs of impairment.

The revision at hand does not impact the acute criterion, which EPA approved in April

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[2] Section 2.20. "Trout waters" are streams or stream segments which sustain year-round trout populations. Excluded are those streams or stream segments which receive annual stockings of trout but which do not support year-round trout populations. Appendix A of the West Virginia regulations lists state waters designated as trout waters.

[3] EPA has approved the application of West Virginia's aluminum criteria to dissolved aluminum as protective of aquatic life. See EPA's April 17, 2003 approval letter sent to West Virginia.

2003. Further, the revision only impacts non-trout waters. Thus EPA considered whether the chronic criterion as revised still protects the aquatic life use in those waters. Although the modification of the chronic criterion is applicable only until July 4, 2007, EPA's review under the CWA of the criterion is no different than if the criterion applied permanently: whether the criterion as modified is protective of the use.

Discussion of EPA's Review

EPA's recommended aquatic life aluminum criteria of 87 $\mu g/l$ for chronic exposure and 750 $\mu g/l$ for acute exposure were published in the 1988 document *Ambient Water Quality Criteria for Aluminum* (EPA 440/5-86-008, August 1988). Using EPA's 1985 guidelines for deriving criteria for protection of aquatic life, the final chronic value for aluminum calculated from chronic toxicity data was 748 $\mu g/L$, which would have supported a chronic criterion of 750 $\mu g/L$. However, because some data showed greater toxicity of aluminum to brook trout and striped bass specifically, EPA decided to lower the chronic criterion to 87 $\mu g/l$ in order to protect these two recreationally important species.

West Virginia has retained the chronic 87 $\mu g/l$ aquatic life aluminum criterion for trout streams. For all other, West Virginia has amended its 87 $\mu g/l$ chronic criterion to 750 $\mu g/l$. This is consistent with the rationale supporting EPA's recommended criteria. Trout are protected by the lower chronic criterion, but in all other waters, the criterion calculated through EPA's guidelines is protective of the aquatic life use. Striped bass, the other species which led to the adoption of a lower recommended chronic criterion, is not a recreationally important species in West Virginia waters. It is not a native species of West Virginia waters - striped bass is an anadromous fish which must spent part of its life cycle in salt water, while West Virginia is a landlocked state. West Virginia does not stock striped bass in its waters; specimens occasionally found in West Virginia are likely to be from the fish stocked in neighboring states. While West Virginia does do annual stocking of hybrid striped bass, hybrid striped bass does not reproduce naturally and thus does not form natural populations. Therefore, other than in trout waters, there is no reason to lower the chronic criterion calculated using EPA guidelines.

As provided in the West Virginia regulations, the modification of the aluminum criteria is effective only till July 4, 2007. In that date, the applicable chronic criterion reverts to 87 $\mu g/L$ in all waters. EPA already deemed that criterion protective, and in any case, it would be more protective than the criterion which the Agency is hereby approving.

In light of these considerations, West Virginia's criteria for aluminum as revised are protective of the aquatic life use.

west virginia department of environmental protection

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Joe Manchin III, Governor
Stephanie R. Timmermeyer, Cabinet Secretary
www.wvdep.org

FAX COVER SHEET

TO: Jason Bostic

FROM: Pat Webb

FAX #: 342-7651

PHONE #:

SUBJECT: EPA Letter

DATE: 1-12-06

RE: as you requested, please call if I can be of further help.
Pat

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ATTACHMENT

E

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

SEP 0 8 2009

Scott G. Mandirola, Director
Water and Waste Management Division
West Virginia Department of Environmental Protection
Charleston, West Virginia 25304

Dear Mr. Mandirola,

The U.S. Environmental Protection Agency (EPA) has completed its review of the revisions to West Virginia's Title 47 Legislative Rule of the Department of Environmental Protection (WVDEP) *Series 2 Requirements Governing Water Quality Standards* (WV WQS Rule). The revisions addressed today were submitted to EPA in a package dated July 31, 2008, pursuant to Section 303(c)(1) of the Clean Water Act (CWA) and 40 C.F.R. Part 131. The WVDEP Associate General Counsel certified on July 31, 2008 that these revisions were duly adopted in accordance with State law and became effective July 1, 2008. EPA Region III received this package on August 6, 2008.

Based on a review of the WVDEP submission and supporting documentation, EPA finds (with one exception) the new or revised provisions that we reviewed are consistent with the CWA and EPA's implementing regulation at 40 CFR Part 131. The enclosure to this letter lists the provisions EPA is approving today and two provisions that WVDEP revised and submitted to EPA but upon which EPA is not acting for reasons explained in that document. This enclosure also discusses the bases for EPA's approval of the provisions upon which we are acting.

Under the Endangered Species Act, EPA has the obligation to determine if our approval of this modification to West Virginia's Water Quality Standards regulation will adversely affect threatened and endangered species and their critical habitat in West Virginia. EPA's biological evaluation found no adverse affect to threatened or endangered species. EPA has completed consultation with U.S. Fish and Wildlife Service and received concurrence with the Agency's findings on October 6, 2008.

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WV DEPARTMENT OF ENVIRONMENTAL PROTECTION
DWWM - DIRECTORS OFFICE

I would like to extend my deep appreciation to you and your staff for WVDEP's exceptional efforts and commitment to work with EPA, to meet our CWA responsibilities. If you have any questions concerning this letter please contact Ms. Cheryl Atkinson at (215) 814-3392.

Sincerely,

Victoria P. Binetti

for Jon M. Capacasa, Director
Water Protection Division

Enclosure

ENVIRONMENTAL PROTECTION AGENCY, REGION III
WEST VIRGINIA REQUIREMENTS GOVERNING WATER QUALITY STANDARDS
2008 TRIENNIAL REVIEW

Today's EPA Region III action letter addresses the revisions to the Title 47 Legislative Rules West Virginia Department of Environmental Protection (DEP) Series 2 Requirements Governing Water Quality Standards (WVWQS rule) submitted to EPA Region III in a letter dated July 31, 2008.

Approval of New and Revised Items

Clerical and Minor Revisions

The following revisions are minor and/or clerical revisions to the State's water quality rules and do not impact the scope of the designated uses or the protectiveness of the water quality criteria:

1. "Stream or stream segment" was replaced with "water" in the definition of "Trout waters" because lakes are also included among such waters.

2. In several sections of WVWQS rule "water body" was replace with "water" or "waters" in an effort to be consistent throughout the WVWQS rule.

3. References to "Board" or "rule making authority" were changed to "Secretary" to reflect current authority.

4. The term "not to exceed" in Table 1 of Appendix E was deleted where it conflicts with aquatic life footnotes 1 and 2.

5. The phrase "[c]oncentration not to be exceeded unless otherwise noted" was added to footnotes 3 and 4 to insure proper application of the human health criteria.

6. In Appendix E, Table 1, Section 8.13, the term "Primary Contact Recreation" was replaced with "Water Contact Recreation" to be consistent with Category C designation as outlined in Section 6.4 of the WVWQS rule.

West Virginia Waters

1. The Section 7.2.d.6.1 (Stony River) variance was deleted because it expired on December 31, 1998. Since then, the applicable temperature criteria have been those in Appendix E, already approved as protective, and more stringent than the criteria in the variance.

2. Section 7.2.d.9 specifically designated Blackwater River as a trout stream, which was repetitive because Blackwater is listed on the trout list in Appendix A. Therefore, Section 7.2.d.9 has been amended. This minor correction does not affect the designation of Blackwater River as a trout stream.

3. The Section 7.2.d.14 Youghiogheny River use exclusion was removed. West Virginia did a documentation search and no justification was found for this use exclusion.

4. In Section 7.2.d.19.3 (Ward Hollow of Davis Creek) the variance for the Union Carbide Corporation's discharge to Ward Hollow of Davis Creek was extended from July 1, 2008 to July 1, 2010. EPA first approved the variance for chloride in September 2006. The basis for the approval was that naturally occurring chloride concentrations prevent attainment. West Virginia asserts in its July 2008 Rationale Document that the natural conditions that led to the variance still apply and that the variance provisions are consistent with 40 CFR 131.10(g). The Region finds that the variance is still consistent with the CWA. See September 26, 2006, letter from Jon Capacasa, EPA Region III Water Protection Division Director to Lisa McClung, WVDEP Water and Waste Management Division.

5. The Section 7.2.d.20.3 (Simmons Creek) variance was deleted because it expired on May 30, 1998. Since then the applicable temperature criteria have been those in Appendix E, already approved as protective, and more stringent than the criteria in the variance.

6. Section 7.2.d.34.1 (Pats Branch) was added to exclude Category A (Public Water Supply) and Category D1 (Irrigation) use designations for Pats Branch, from its confluence with the Guyandotte River to a point 1000 feet upstream. The remaining designated uses applicable to this section of Pats Branch are Category B1 (Warm Water Fishery), Category C (Water Contact Recreation) and Subcategory D3 (wildlife). The Region has reviewed the following documents submitted by the State in support of the State's use designation changes:

   - Application for a Use Determination of Downstream Segment of Pats Branch, dated May 8, 2006, prepared by Triad Engineering for Hunting Alloys Corporation.
   - Pats Branch Storm Sewer Study dated October 2006, prepared by Triad Engineering for Special Metal Corporation.
   - Use Removal Request Information Sheet, prepared by WVDEP.
   - Rationale Document dated July 31, 2008, prepared by WVDEP.

- Memo from Pat Campbell to Jason Morgan dated March 20, 2006, regarding a Survey Reconnaissance of Pats Branch.

To remove a designated use, the State has to show that the use is not an existing use and that the use is not attainable due to one of the reasons listed in 40 CFR 131.10(g). In addition, EPA considers whether the revised use designations and criteria are consistent with other requirements of 40 CFR Part 131, including the provision under 40 CFR 131.10(b) ensuring the protection of downstream waters.

The documents in support of the use change describe the physical conditions of the stream segment to which the use removal applies: the stream segment begins when Pats Branch enters a six-foot diameter concrete culvert beneath the Huntington Alloys Corporation facility. The culvert runs about 25 feet below the ground surface for about 600 feet. Pats Branch then resurfaces about 50 feet before a flood wall. At this location there is also a City of Huntington combined sewer overflow discharge point. Pats Branch then continues in another underground culvert for 350 feet, going beneath the flood wall until it discharges into the Guyandotte River via a submerged pipe. According to the State, Pats Branch has been channeled through underground culverts in this segment for at least forty (40) years. West Virginia asserts that because of these physical conditions this segment of Pats Branch cannot be used for drinking water or for irrigation. Based upon construction drawings, data base searches, personal interviews and physical surveys, the State asserts that this section of Pats Branch does not have water intake pipes or other evidence that suggests that the stream segment is used as a drinking water source or source of irrigation. The stream segment does not have adjacent residential or agriculture areas and does not have ground water wells within one mile of the downstream segment of Pats Branch. The State also asserts that, based on a review of stream monitoring data, the use removal will cause no measurable impacts to downstream waters.

The State bases this use change on 40 CFR 131.10(g)(4), which provides for use removal when "dams, diversions or other types of hydrologic modifications preclude the attainment of the use and it is not feasible to restore the water to its original condition or to operate such modification in a way that would result in the attainment of the use." The State asserts hydrological modifications preclude restoring Pats Branch to its original condition and restoration is infeasible because of the "heavy industrialization of the area and the City of Huntington flood wall."

Based on review of the WVWQS revisions and the supporting evidence, the Region has concluded that the revisions are consistent with federal requirements at 40 CFR Section 131.10. Accordingly, the Region approves the Category A and D1 use exclusion from Pats Branch.

Appendix E Human Health Based Criteria

The State adopted several revisions to the Human Health criteria established in Appendix E, Table 1, as outlined below.

- Appendix E, Table 1, Section 8.4 - The State's prior human health criterion of 50ug/L arsenic was based on the Maximum Contaminant Level (MCL) for drinking water established by EPA under the Safe Drinking Water Act (SDWA). The State here revised its criterion in accordance with EPA's new MCL of 10 ug/L. Adoption of the MCL for arsenic is appropriate for the protection of water supply uses (see Section 3.2.4 of the Water Quality Standards Handbook). Accordingly, the Region approves the revision.

- Appendix E, Table 1, Section 8.23 - The rule updates the benzene criterion for Human Health Category C from 71 ug/L to the EPA recommended value of 51 ug/L. The criterion meets the requirement of 40 CFR 131.11 and is scientifically defensible as explained in 65 Fed. Reg 66443 (Nov. 3, 2000) and supporting documents. Accordingly, the Region approves the revision.

- Appendix E, Table 1, Section 8.13.1 now includes a Fecal Coliform criterion to protect Category A use in the non-recreation season of November–April on the Ohio River. This change makes the criteria consistent with the Ohio River Valley Water Sanitation Commission (ORSANCO) Water Quality Standards. Specifically, during the non-recreation season (November 1st to April 1st) the maximum allowable level of fecal coliform from the Ohio River shall not exceed 2,000 counts per 100 mL as a monthly geometric mean based on not less than 5 samples per month. The West Virginia rationale document asserts that the ORSANCO fecal coliform criteria of 2,000 counts per 100 mL (for the protection of public water supply uses) are based on EPA's Blue Book recommendation which states that "[I]n light of the capability of the chlorination treatment process for raw surface water, it is recommended that the geometrical means of fecal coliform and total coliform densities in raw surface water sources not exceed 2,000/100 ml and 20,000/100 ml, respectively." The criterion meets the requirement of 40 CFR 131.11 and is scientifically defensible. Accordingly, the Region approves the criterion.

- Appendix E, Table 1, Section 8.23 - The halomethanes criterion has been removed and replaced with the four individual halomethane criteria for Bromoform, Dichlorobromomethane, Methyl Bromide and Methylene Chloride. All of these criteria are the same as the EPA's current National Recommended Water Quality Criteria under CWA Section 304(a) for the protection of human health. The criteria meet the requirement of 40 CFR 131.11 and are scientifically defensible as explained in 65 Fed. Reg 66443 (Nov. 3, 2000) and supporting documents. Accordingly, the Region approves the revision.

- Appendix E, Table 1, Section 8.23 - The criterion for polynuclear aromatic hydrocarbons (PAH) has been removed and replaced with the individual criteria for the compounds that make up this group. The 12 PAH compounds for which the State has adopted new criteria are: Acenaphthene, Anthracene, Benzo(a) Anthracene, Benzo(a) Pyrene, Benzo(b) Fluoranthene, Benzo(k) Fluoranthene, Chrysene, Dibenzo (a,h) Anthracene, Fluorene, Ideno (1,2,3-cd) Pyrene, Pyrene, and 2-Chloronaphthalene. All of the new PAH criteria are consistent with the latest CWA Section 304(a) criteria recommendations for the protection of human health. The criteria meet the requirement of 40 CFR 131.11 and are scientifically defensible as explained in 65 Fed. Reg 66443 (Nov. 3, 2000) and supporting documents. Accordingly, the Region approves the revision.

- A footnote was added to the phthalate esters group in Appendix E, Table 1, Section 8.23 to clarify which phthalates are included in the total. This minor clarification does not change the scope of the criteria.

- Appendix E, Table 1, Section 8.27 - The selenium criterion for Category A is changed from10ug/l to 50ug/l to make it consistent with the Maximum Contaminant Level for drinking water set by EPA under the Safe Drinking Water Act. Because the criterion is protective of the use, the Region approves the revision.

Appendix E Aquatic Life Based Criteria

- In Appendix E, Table 1, Section 8.1, the dissolved aluminum chronic criterion for warm water aquatic life was changed from 87xCF to 750xCF, and Footnote e was deleted. Prior to this revision, Footnote e provided that the chronic criterion for warm water aquatic life was to be 750xCF until July 2007. EPA approved that chronic criterion on January 9, 2006 as protective of the use and consistent with the CWA regulations. In June 2007, the DEP filed a temporary emergency rule to continue to apply the modified chronic criterion, and EPA approved the emergency rule on July 5, 2007. The current revision modifies the chronic criterion permanently. Because EPA has already found that the criterion is protective of the use and consistent with the CWA regulations, therefore, the Region approves this revision. See January 9, 2006, letter from Jon Capacasa, EPA Region III Water Protection Division Director to Lisa McClung, WVDEP Water and Waste Management Division.

- Appendix E, Table 1, Section 8.4.1 - The dissolved trivalent arsenic chronic and acute criteria have been updated from 360ug/L and 190ug/L to 340ug/L and 150ug/L based on the EPA recommended criteria. The units (ug/l) were added to the dissolved trivalent arsenic column in Appendix E, Table 1 to clarify the units. The criteria meet the requirement of 40 CFR 131.11 and are scientifically defensible as explained in 65 Fed. Reg. 31682 (May, 2000) and supporting documents. Accordingly, the Region approves the revision.

- Appendix E, Table 1, Sections 8.4.1 and 8.9.1 - The correction factors (CF) were removed for dissolved trivalent arsenic and chromium, dissolved hexavalent because the EPA values are based on dissolved criteria not total. Therefore they do not need to be converted. Because these changes meet the requirements of 40 CFR 131.11, the Region approves the revision.

- Appendix E, Table 1, Sections 8.7.2, 8.7.3, 8.10.1, 8.10.2, 8.19.1, 8.18.2, 8.28.2, 8.34 and 8.34.1 - The revisions for cadmium, copper, nickel, silver and zinc formulas are consistent with the latest CWA Section 304(a) criteria recommendations for the protection of aquatic life issued by EPA. Accordingly, the Region approves the revision. The criteria meet the requirement of 40 CFR 131.11 and are scientifically defensible as explained in 65 Fed. Reg. 31682 (May, 2000) and supporting documents.

Antidegradation Tier 2.5 designation

Section 4.1.c. Tier 2.5 Protection of the WVWQS rule was removed. This leaves a three-tiered antidegradation approach, including Tiers 1, 2 and 3. West Virginia also amended its Tier 3 definition to include within Tier 3 some waters previously classified as Tier 2.5. Five categories of streams previously under Tier 2.5 will now be classified as Tier 3. As revised, the WVWQS rule on antidegradation is consistent with EPA's antidegradation regulation at 40 CFR 131.12. The Tier 2.5 classification which the State removed was at the discretion of the State to have a more stringent provision. Accordingly, all revisions to the antidegradation section of this WVWQS rule are approved today.

Revisions Where EPA is Taking No Action

Today the Region is taking no action on the revision to Section 7.2.d.16.2, which extended the Weirton Steel Corporation socio-economic variance from July 1, 2007 until July 1, 2009. The variance expired on July 1, 2009, and this is therefore no longer effective.

EPA is also deferring action on the proposed lake nutrient criteria in Section 8.3, together with the definition of cool water lakes in Section 2.2 and Appendix F listing cool water lakes. EPA is currently evaluating the scientific justification for the proposed lake nutrient criteria. Additional, more recent data offered by WV in March 2009 as additional justification for the proposed criteria is being evaluated by EPA to determine if the new data is applicable and whether or not that data provides any additional scientific support to the submitted rationale. After a full evaluation of the scientific defensibility of the criteria, EPA will conclude the review of these new criteria.

Fredric P. Andes
Barnes & Thornburg
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Chicago, IL 60606

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Janet Pittman
Rules Branch - Legal Counsel MC 65-46
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100 N. Senate Aevnue
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